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**Akbarian et al.**

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(54) **SYSTEM AND METHOD FOR DETECTING VEHICULAR DOOR MOVEMENT DUE TO NON-CONTACT USING OBSTACLE DETECTION**

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(Continued)

(51) **Int. Cl.**  
**E05F 15/73** (2015.01)  
**B60R 16/03** (2006.01)  
**G01S 13/931** (2020.01)

(52) **U.S. Cl.**  
CPC ..... **E05F 15/73** (2015.01); **B60R 16/03** (2013.01); **G01S 13/931** (2013.01);  
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(58) **Field of Classification Search**  
CPC . E05F 15/73; E05F 15/42; E05F 15/79; E05F 2015/767; E05F 15/74; E05F 15/76;  
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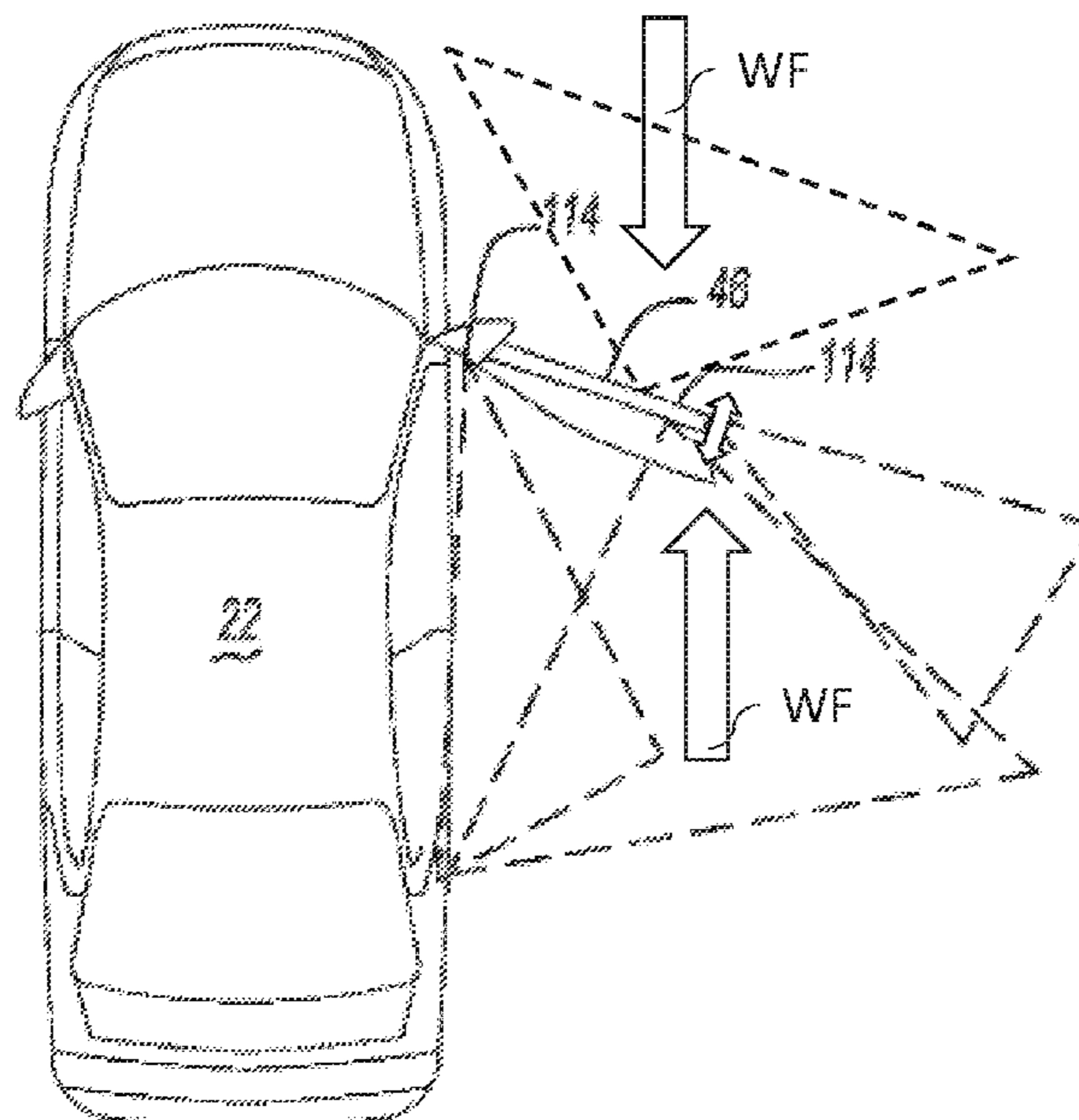
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(57) **ABSTRACT**

A non-contact obstacle detection (NCOD) system for a motor vehicle and a method of operating the non-contact obstacle detection system are disclosed. The NCOD system includes a main electronic control unit adapted to connect to a power source. At least one non-contact obstacle sensor is coupled to the main electronic control unit for detecting obstacles near a closure member of the vehicle. The control unit is configured to detect movement of the closure member, detect no obstacle using the at least one non-contact obstacle sensor, and alter movement of the closure member in response to no obstacle being detected while movement of the closure member is detected.

**11 Claims, 27 Drawing Sheets**



**Related U.S. Application Data**

(60) Provisional application No. 62/460,152, filed on Feb. 17, 2017, provisional application No. 62/327,317, filed on Apr. 25, 2016.

(52) **U.S. Cl.**  
CPC ... *E05Y 2900/531* (2013.01); *E05Y 2900/546* (2013.01); *G01S 2013/9324* (2020.01)

(58) **Field of Classification Search**  
CPC ..... *E05F 15/77*; *B60R 16/03*; *G01S 13/931*; *G01S 2013/9324*; *G01S 2013/93274*; *G01S 2013/9315*; *G01S 17/87*; *G01S 17/931*; *G01S 2015/937*; *G01S 15/87*; *G01S 13/9323*; *G01S 13/87*  
See application file for complete search history.

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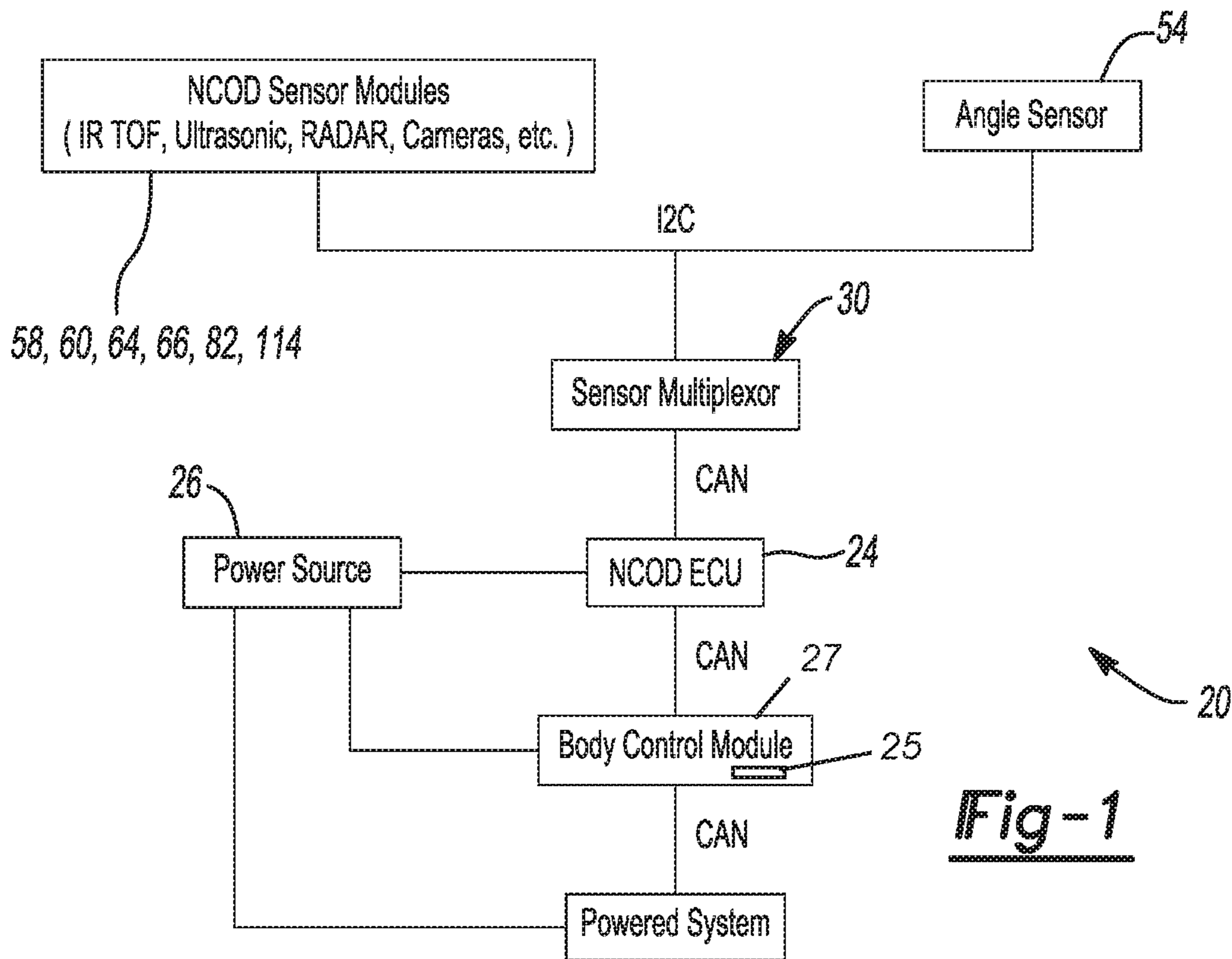


Fig-1

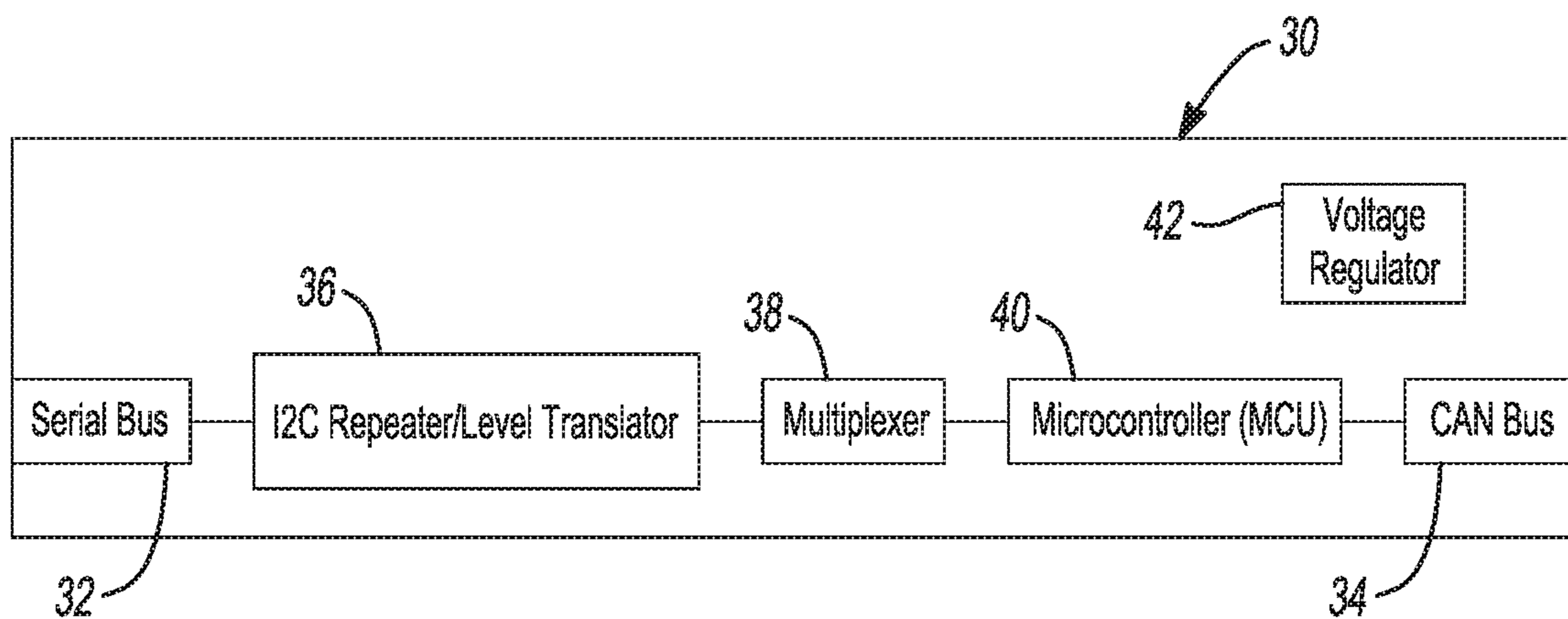
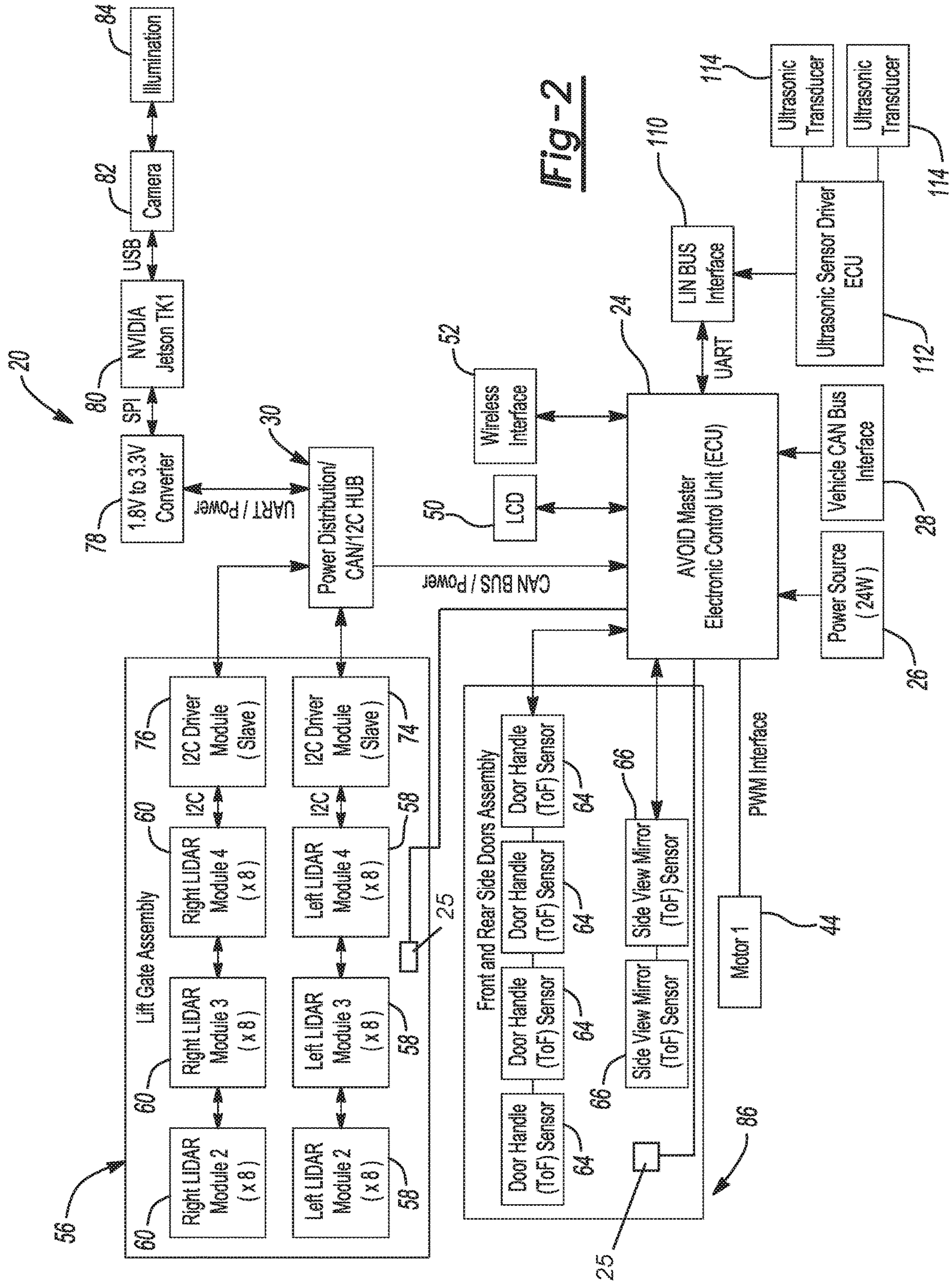


Fig-3



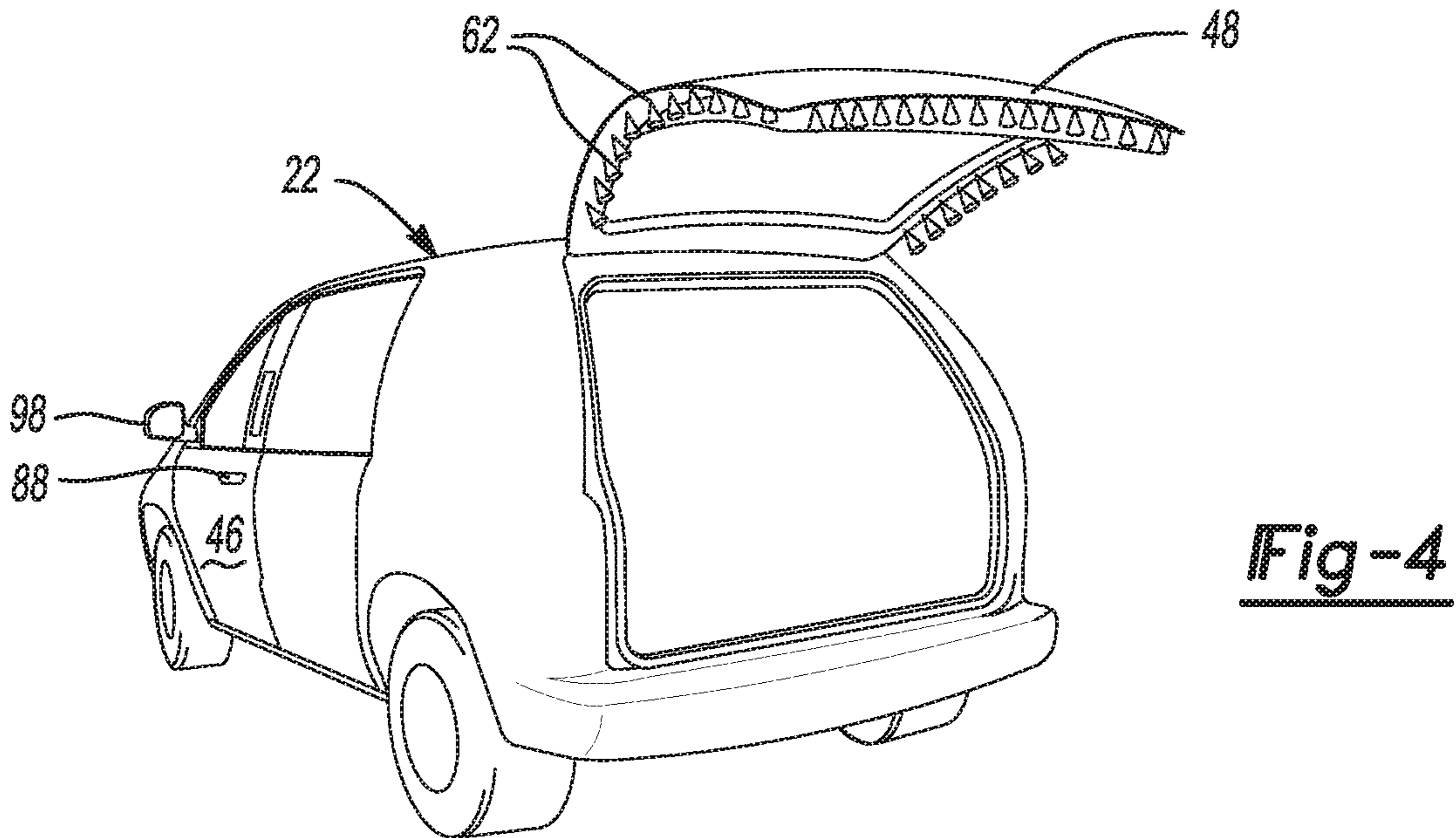


Fig-4

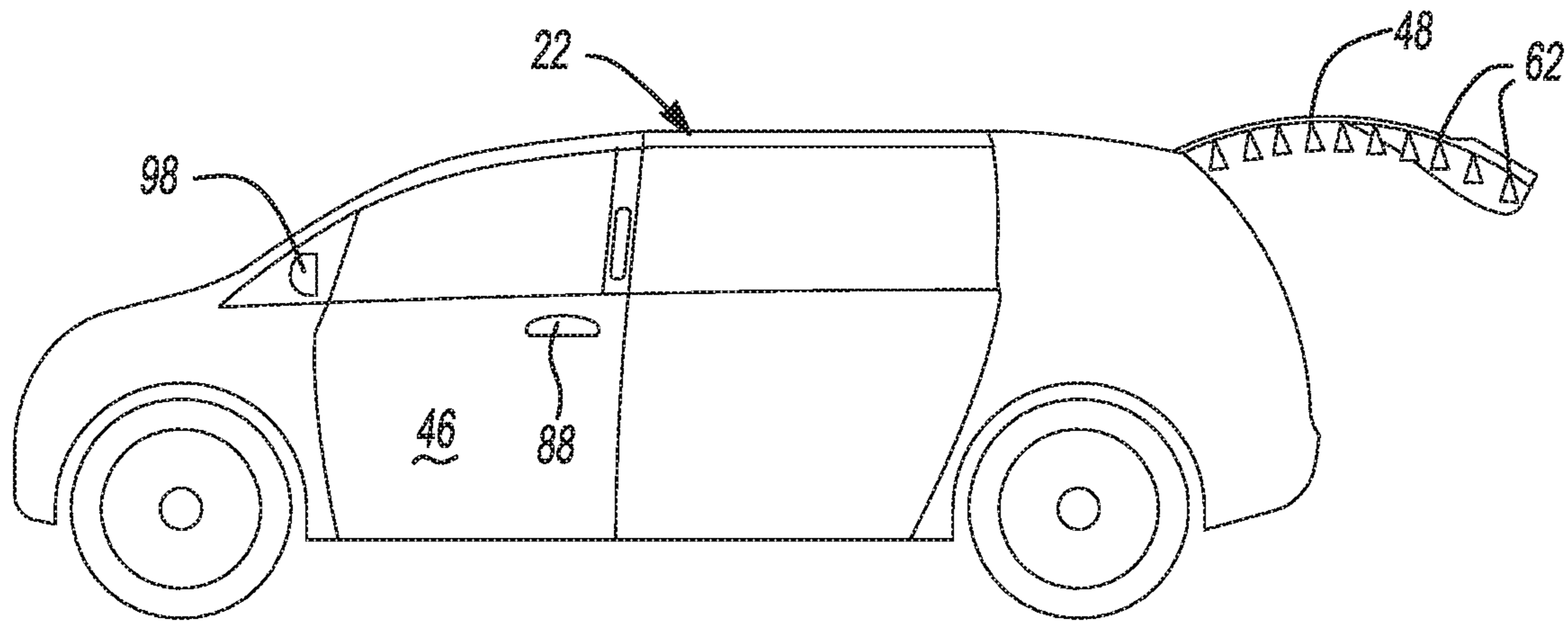


Fig-5A

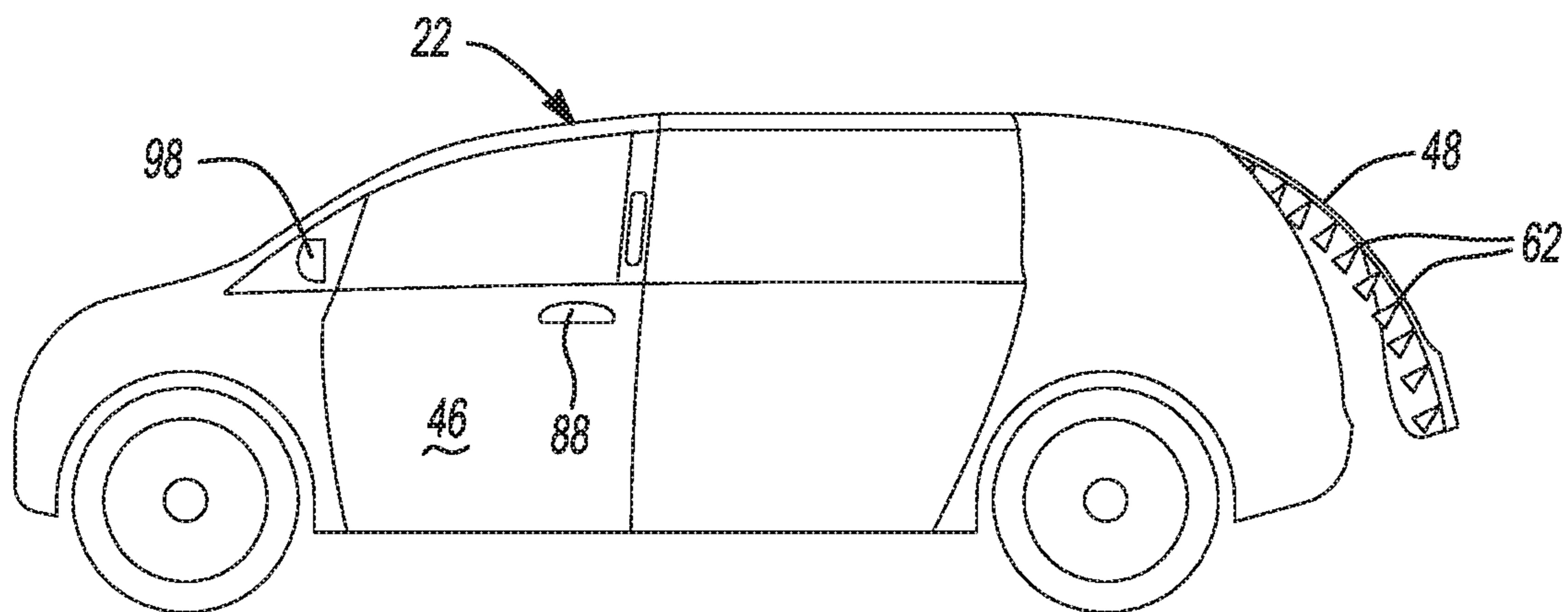


Fig-5B

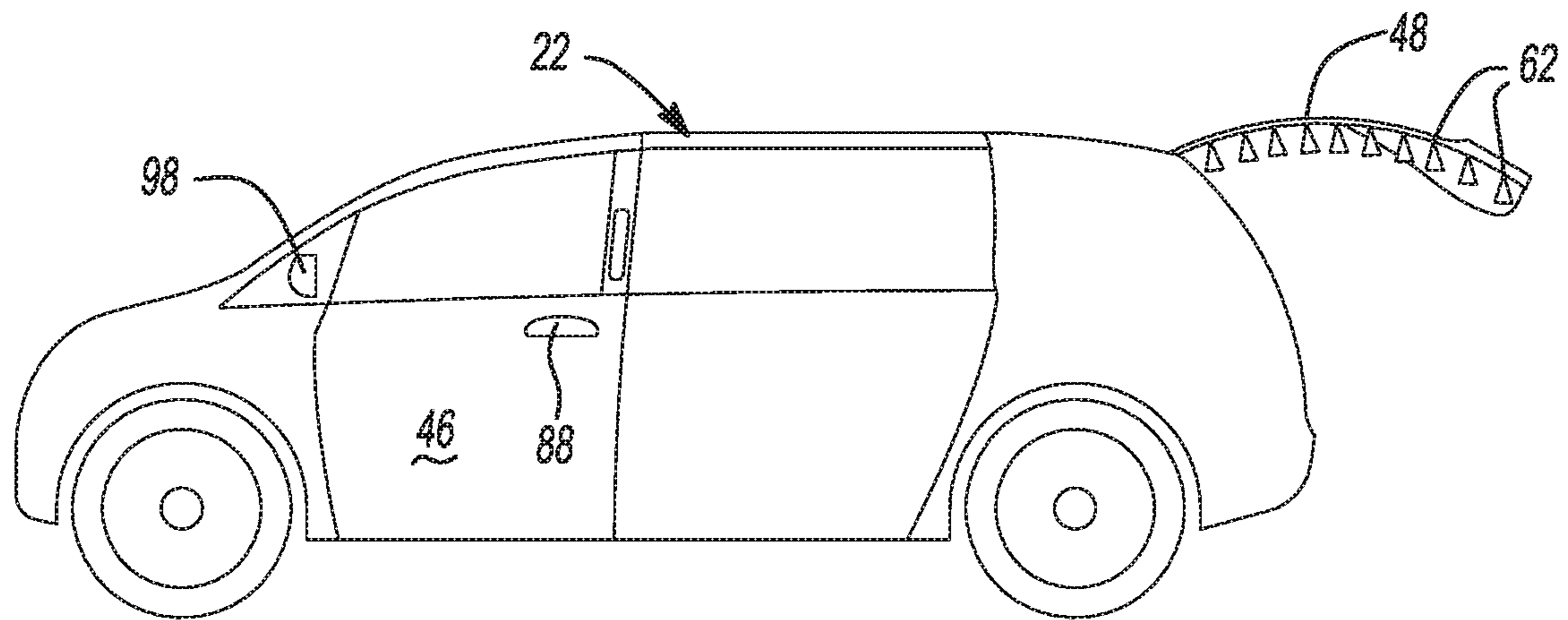


Fig-6A

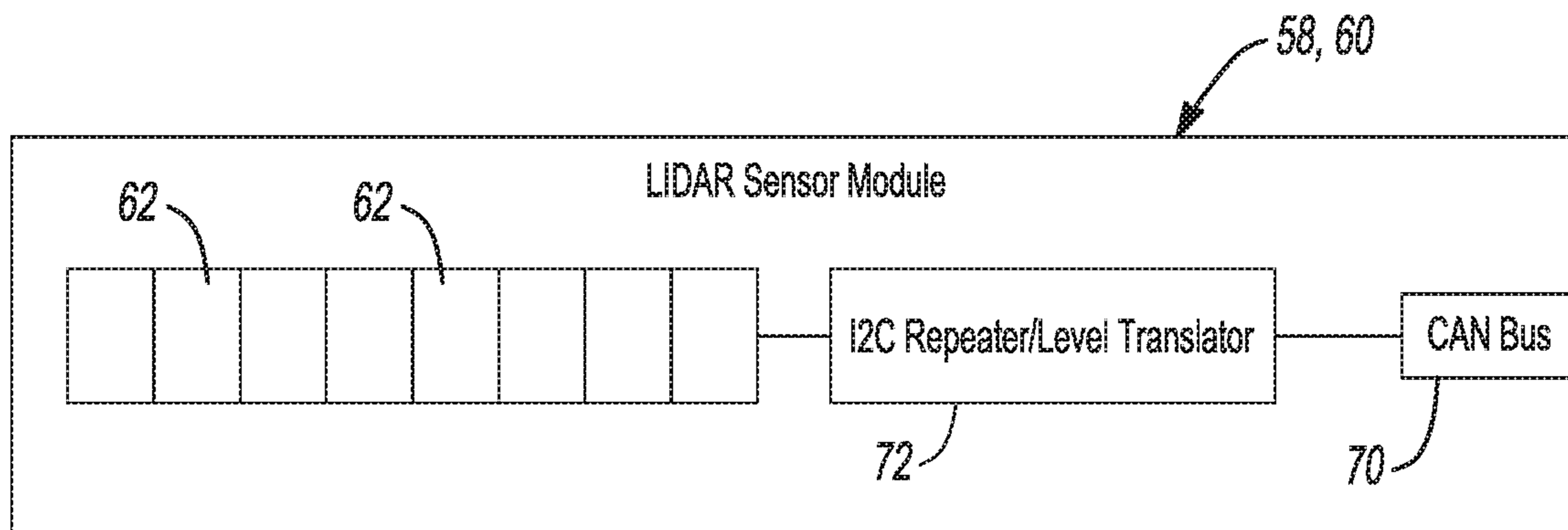


Fig-6B

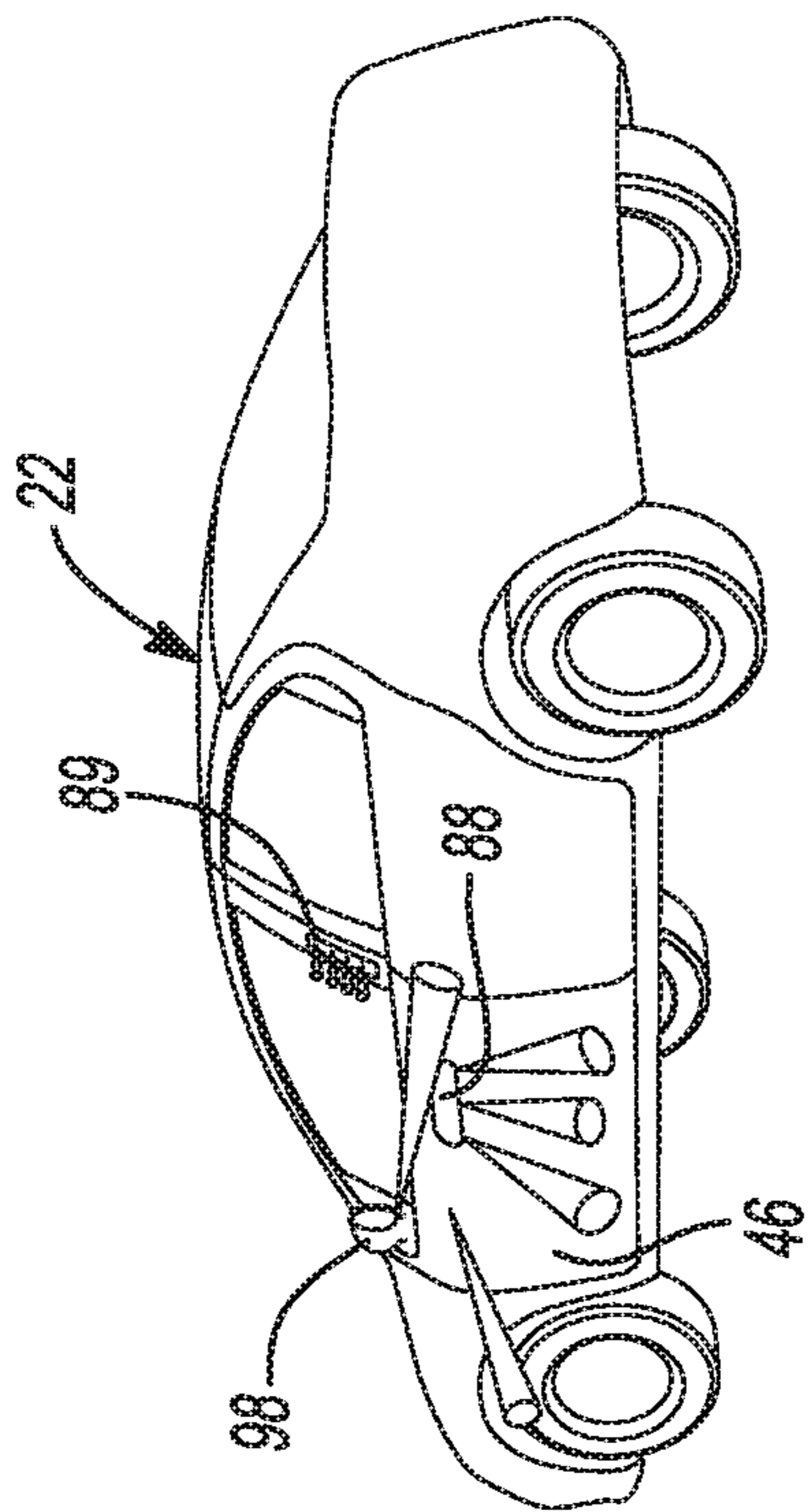


Fig-7A

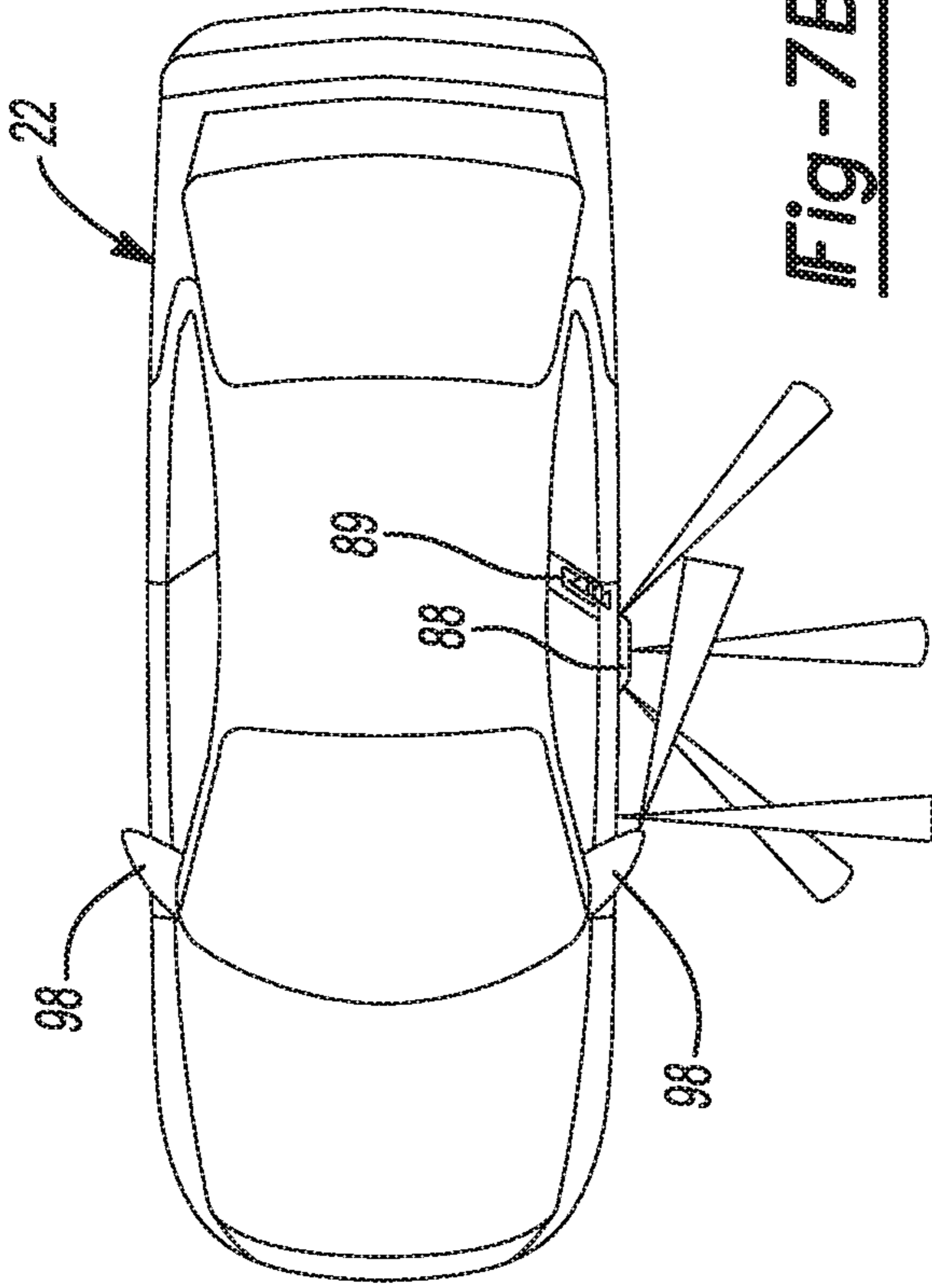


Fig-7B

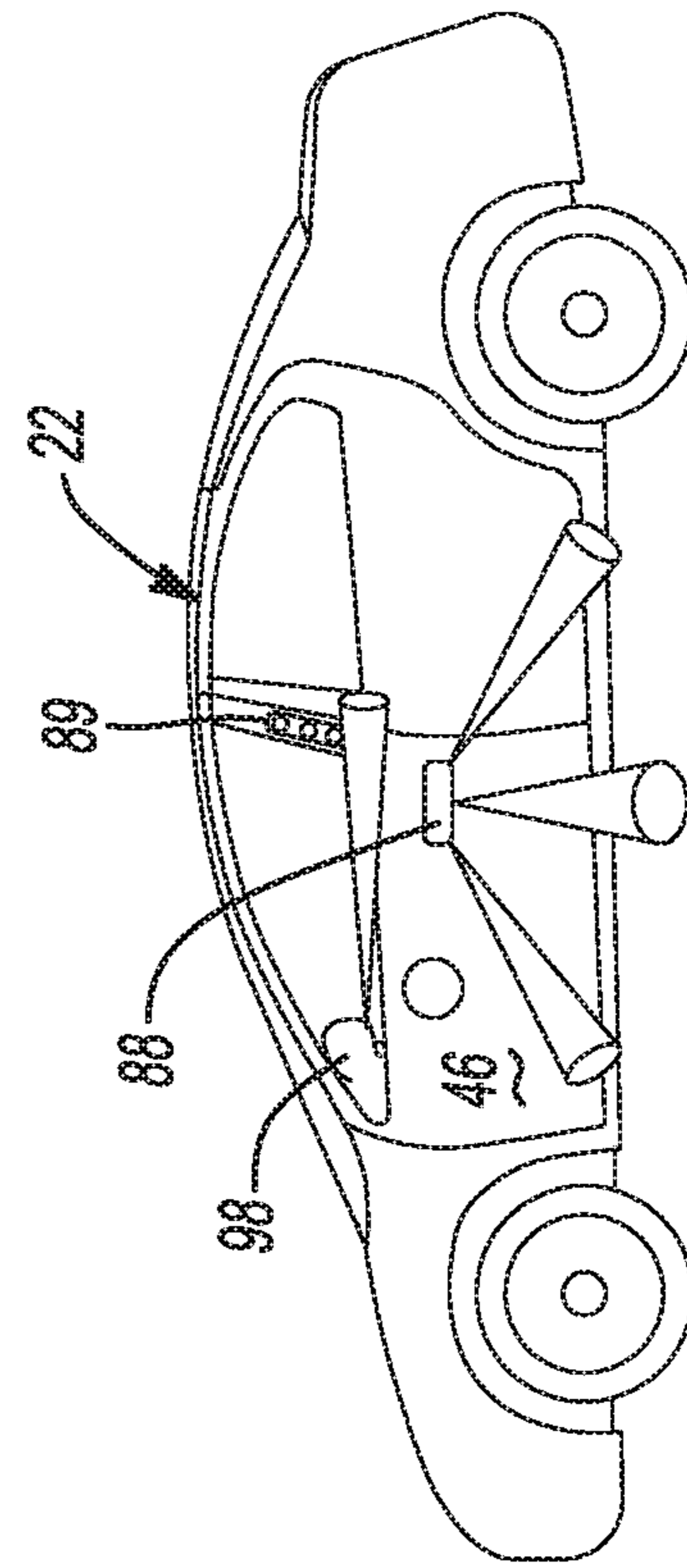


Fig-7C

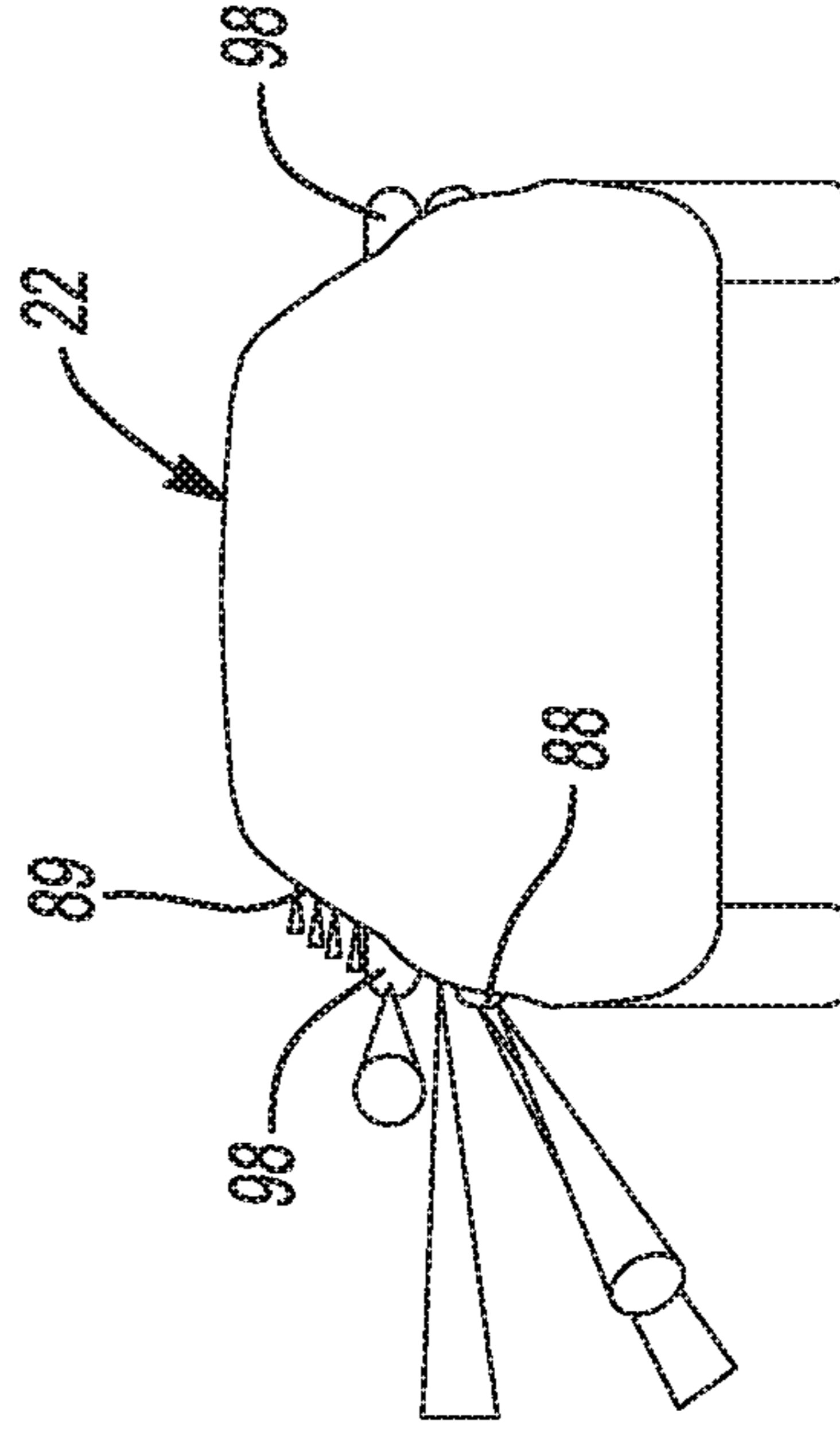


Fig-7D

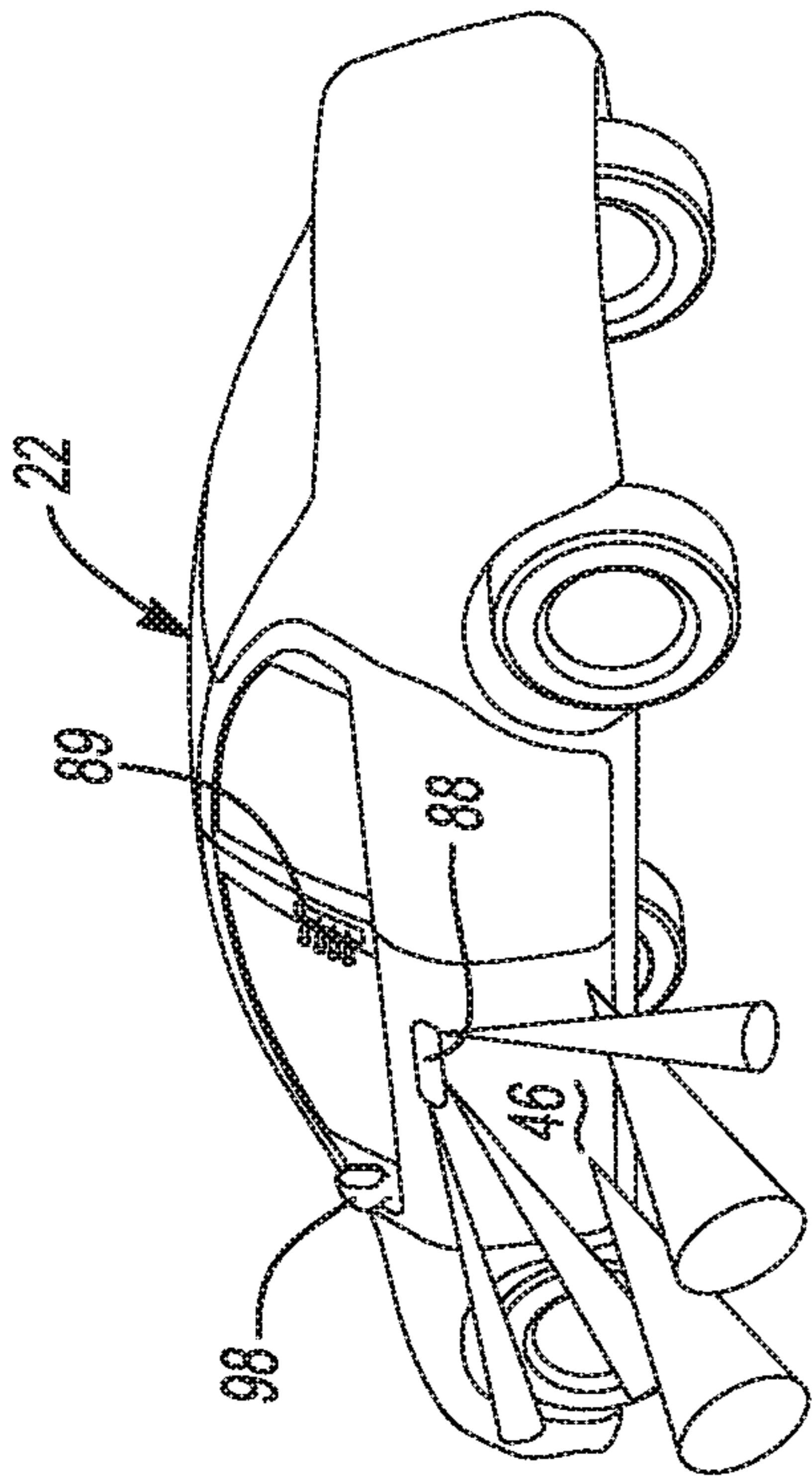


Fig-8A

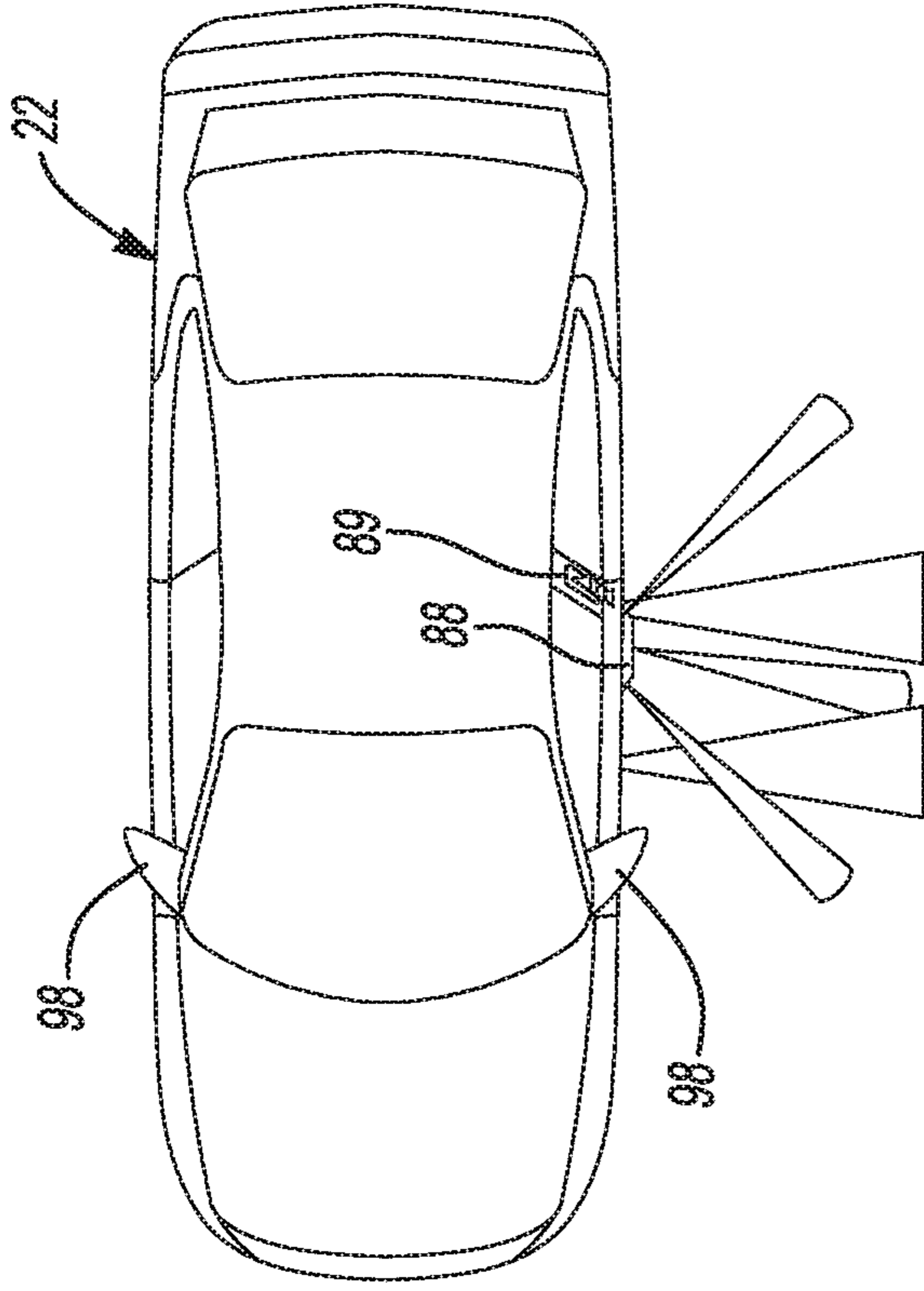


Fig-8B

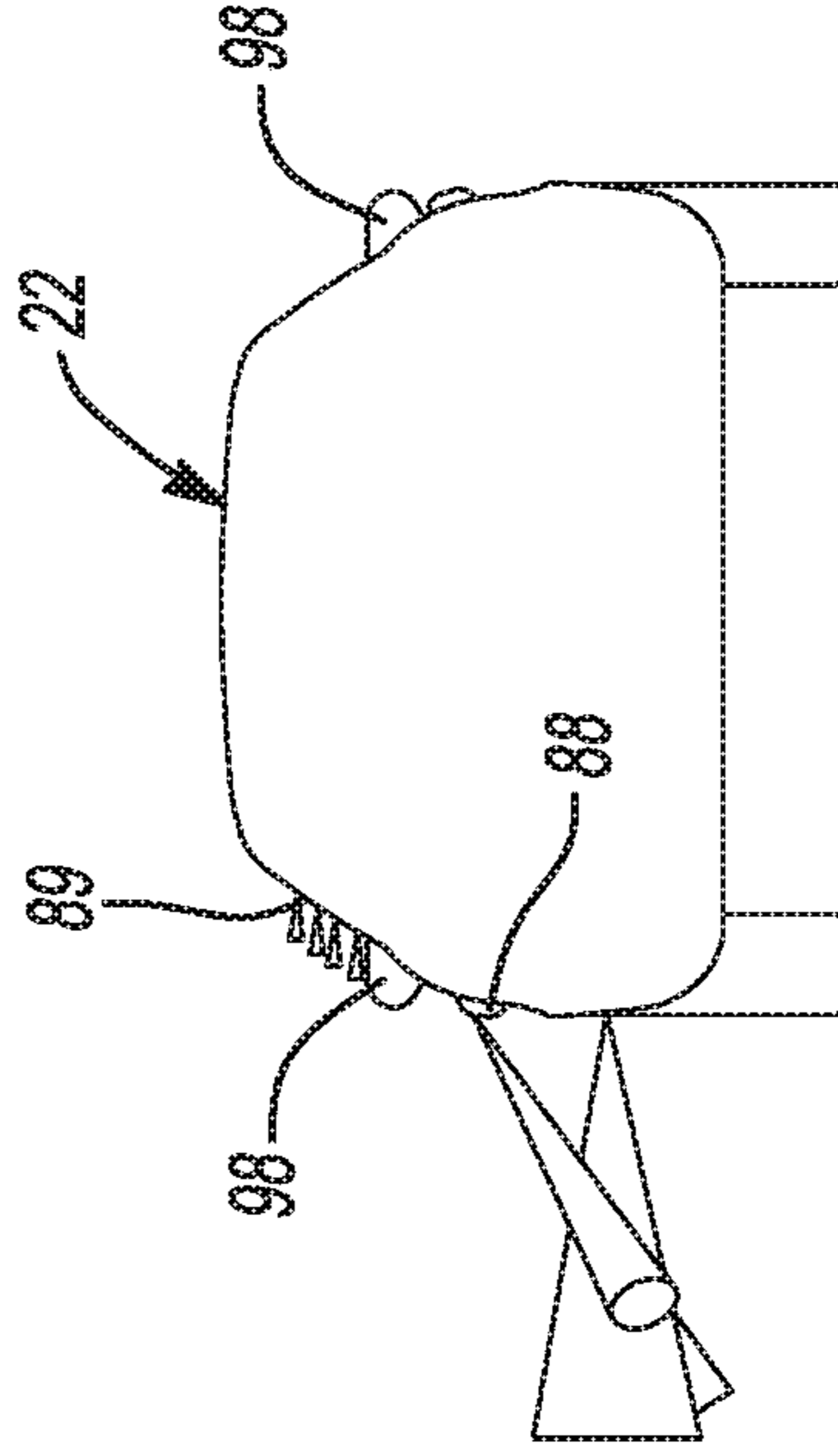


Fig-8D

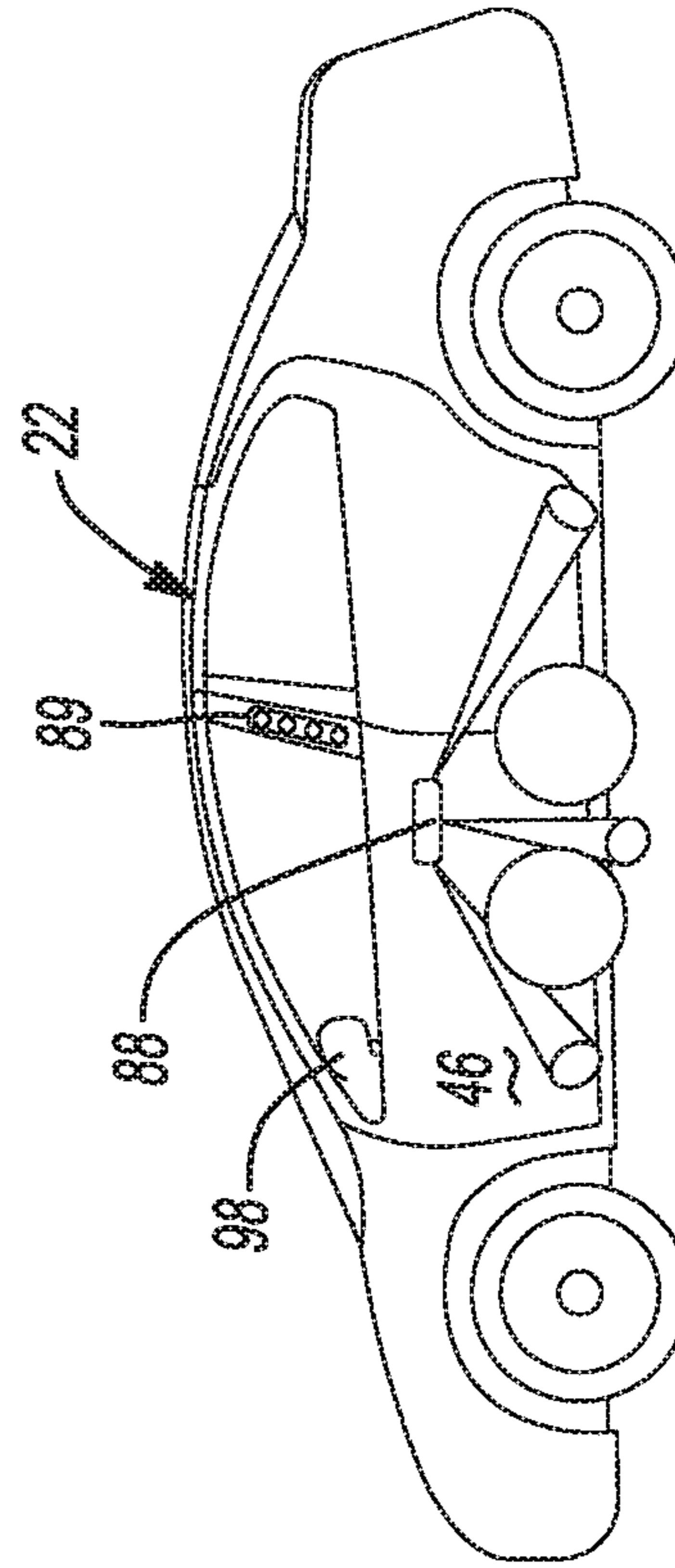


Fig-8C



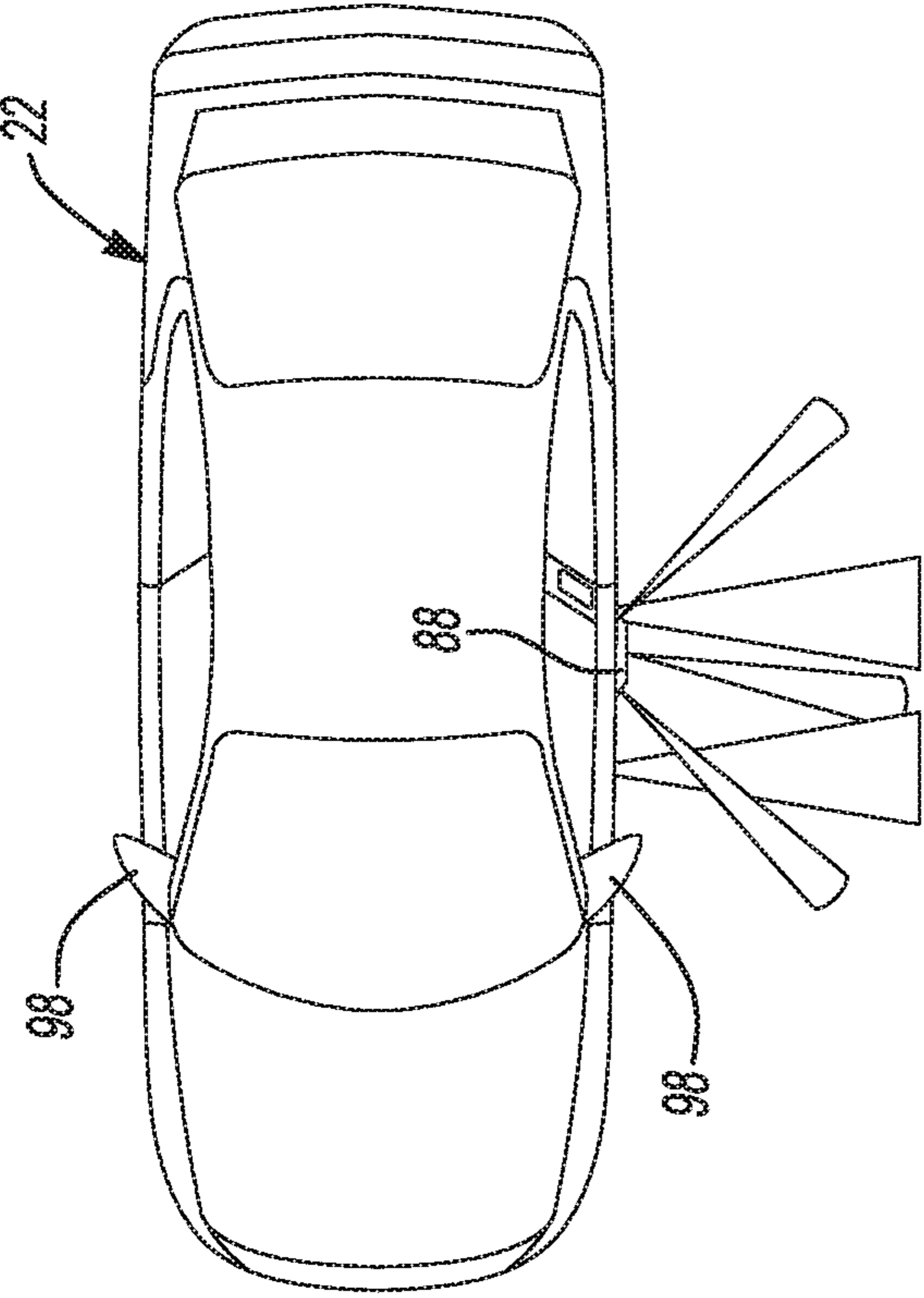


Fig-9B

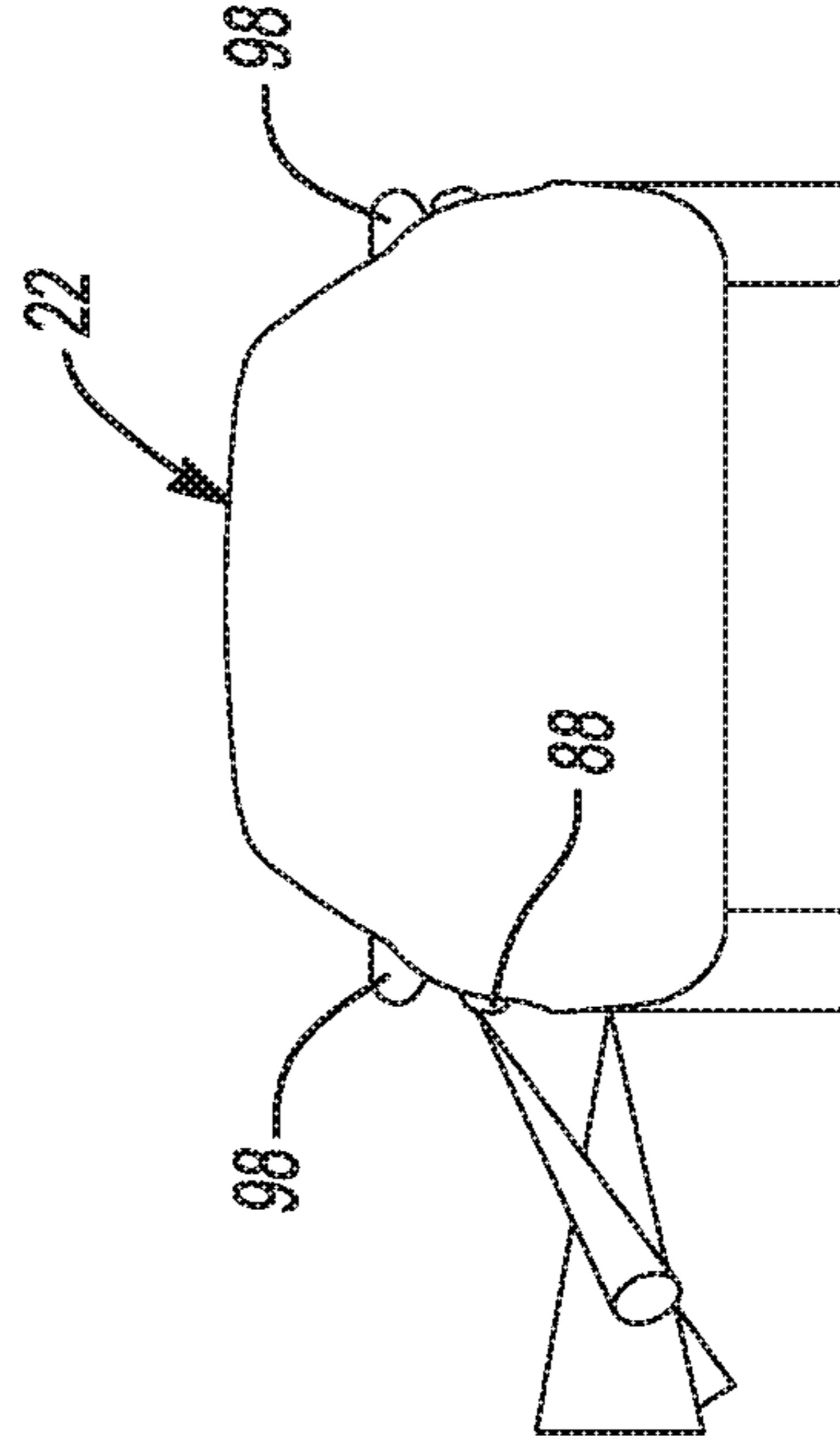


Fig-9D

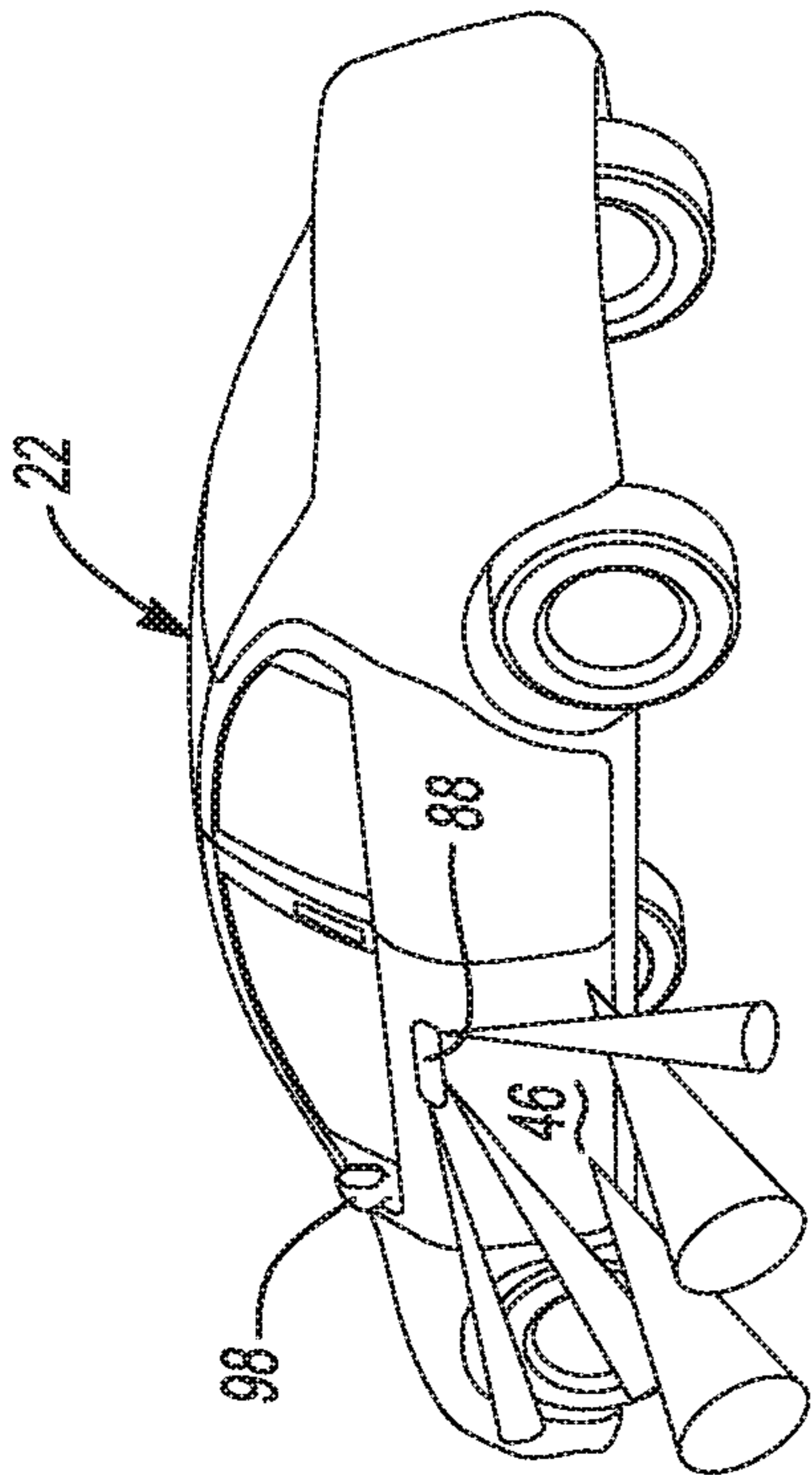


Fig-9A

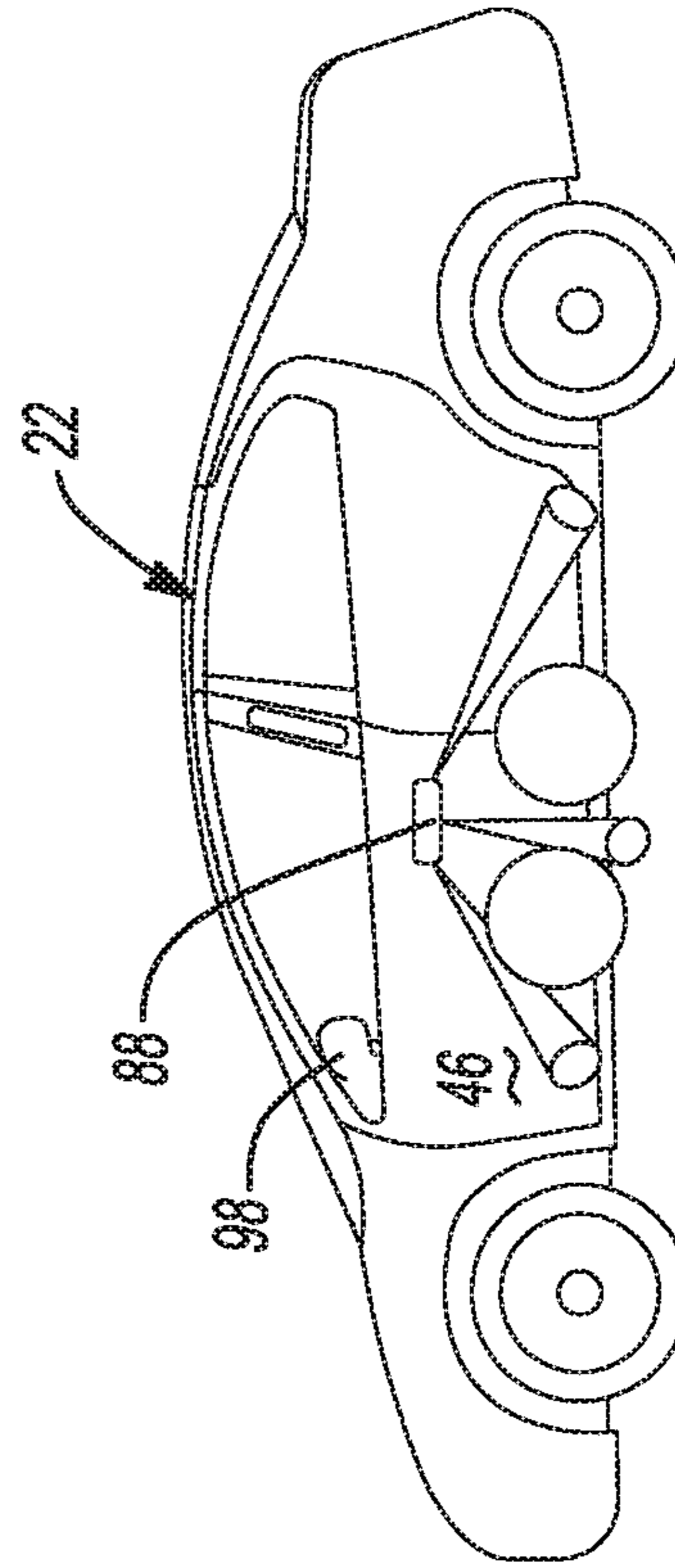


Fig-9C

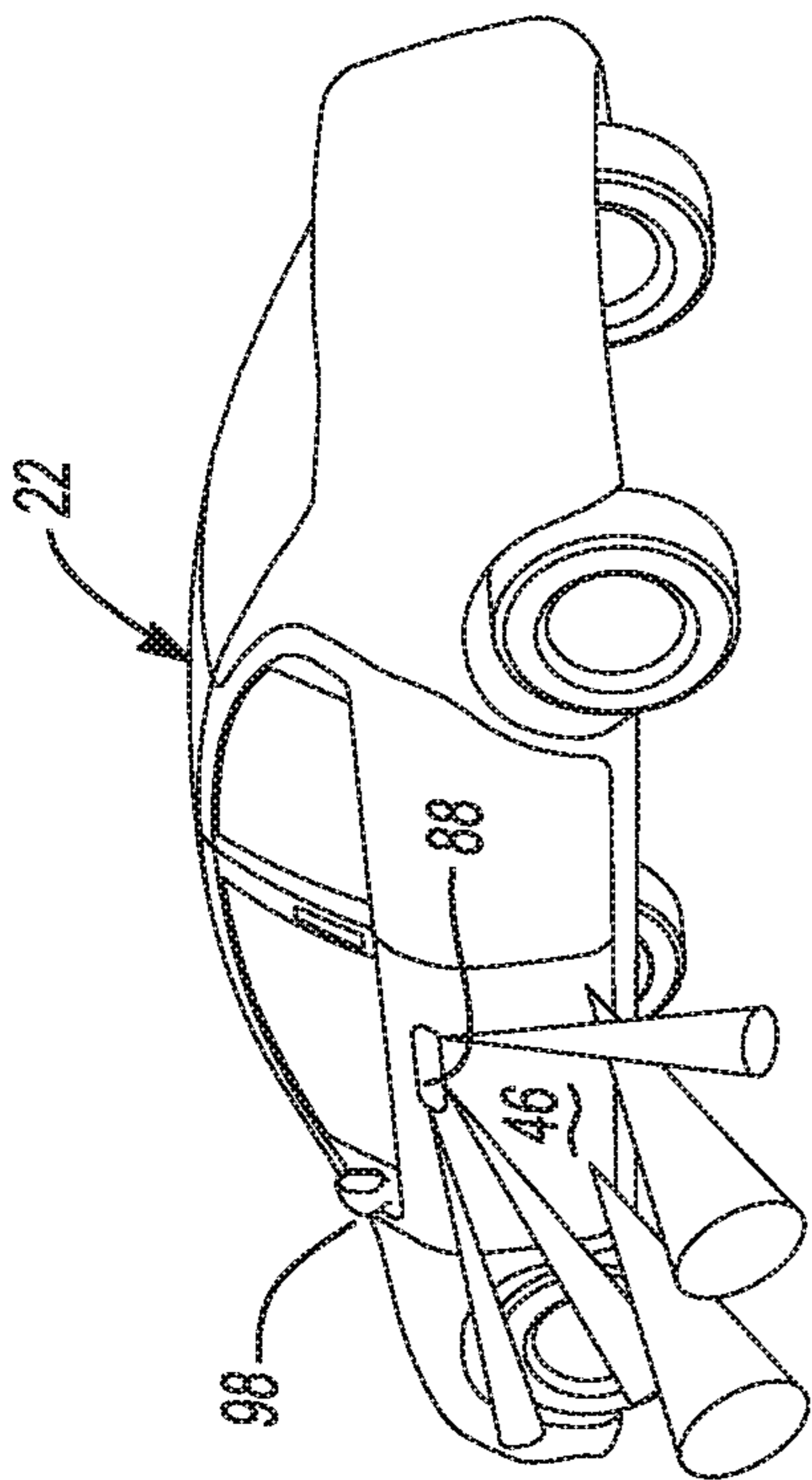


Fig-10A

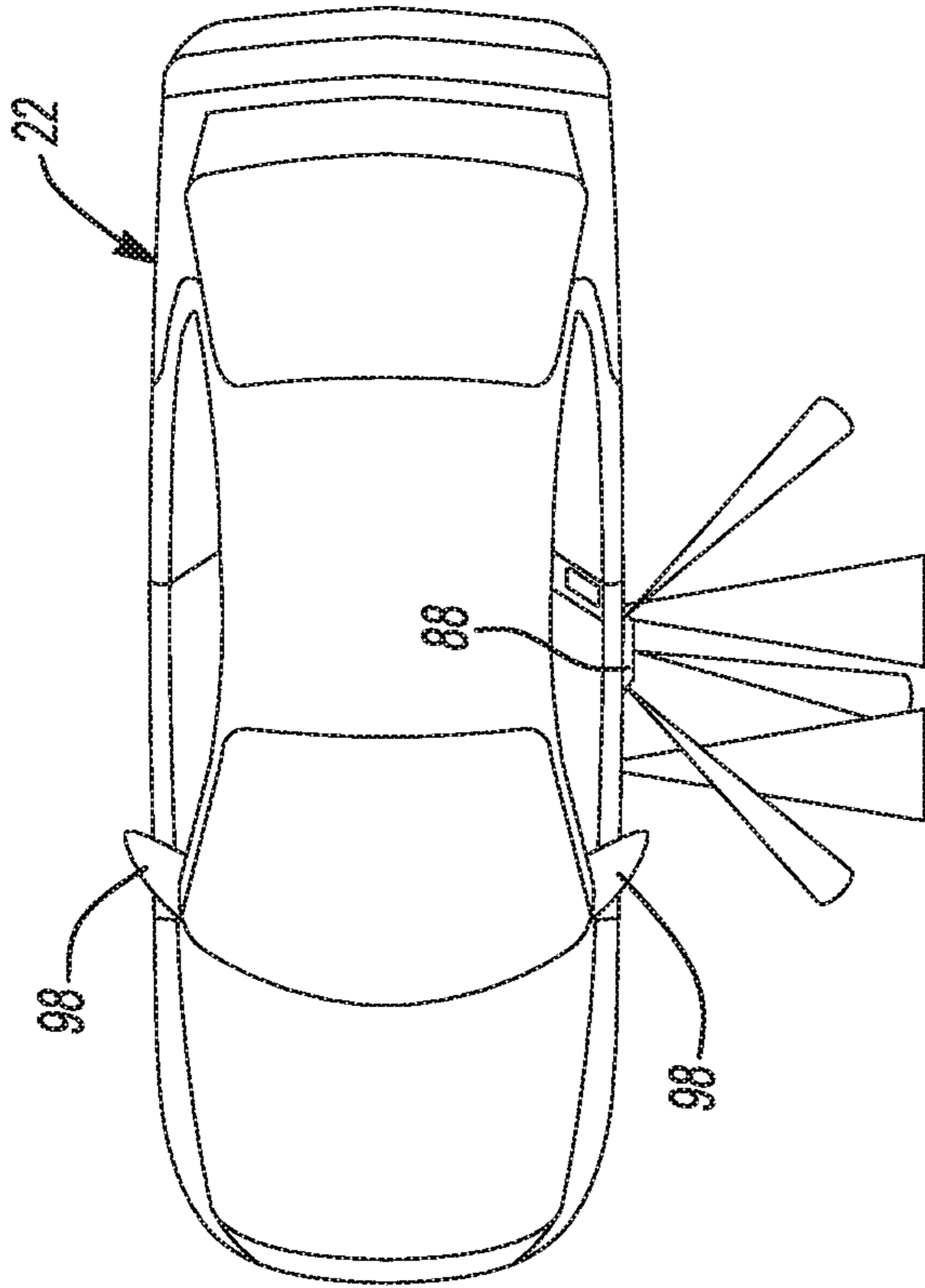


Fig-10B

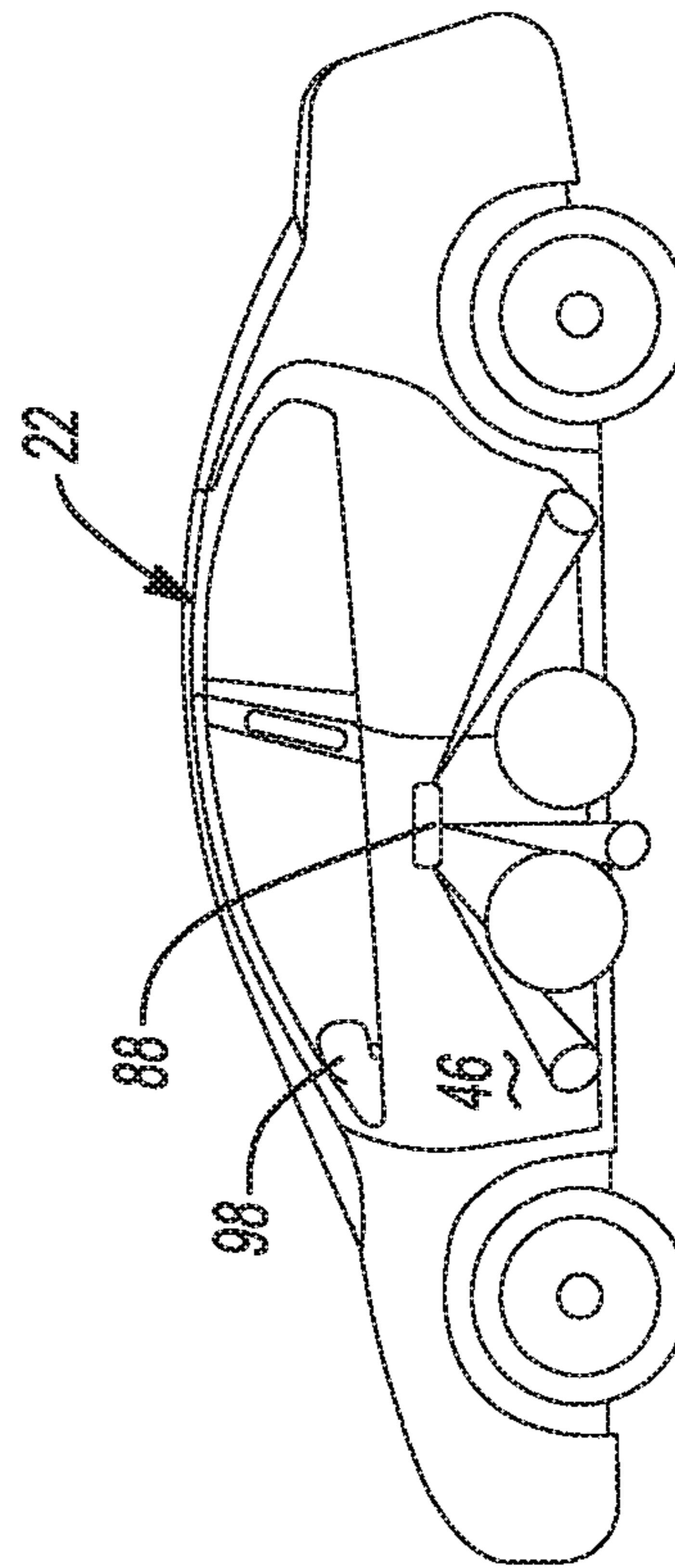


Fig-10C

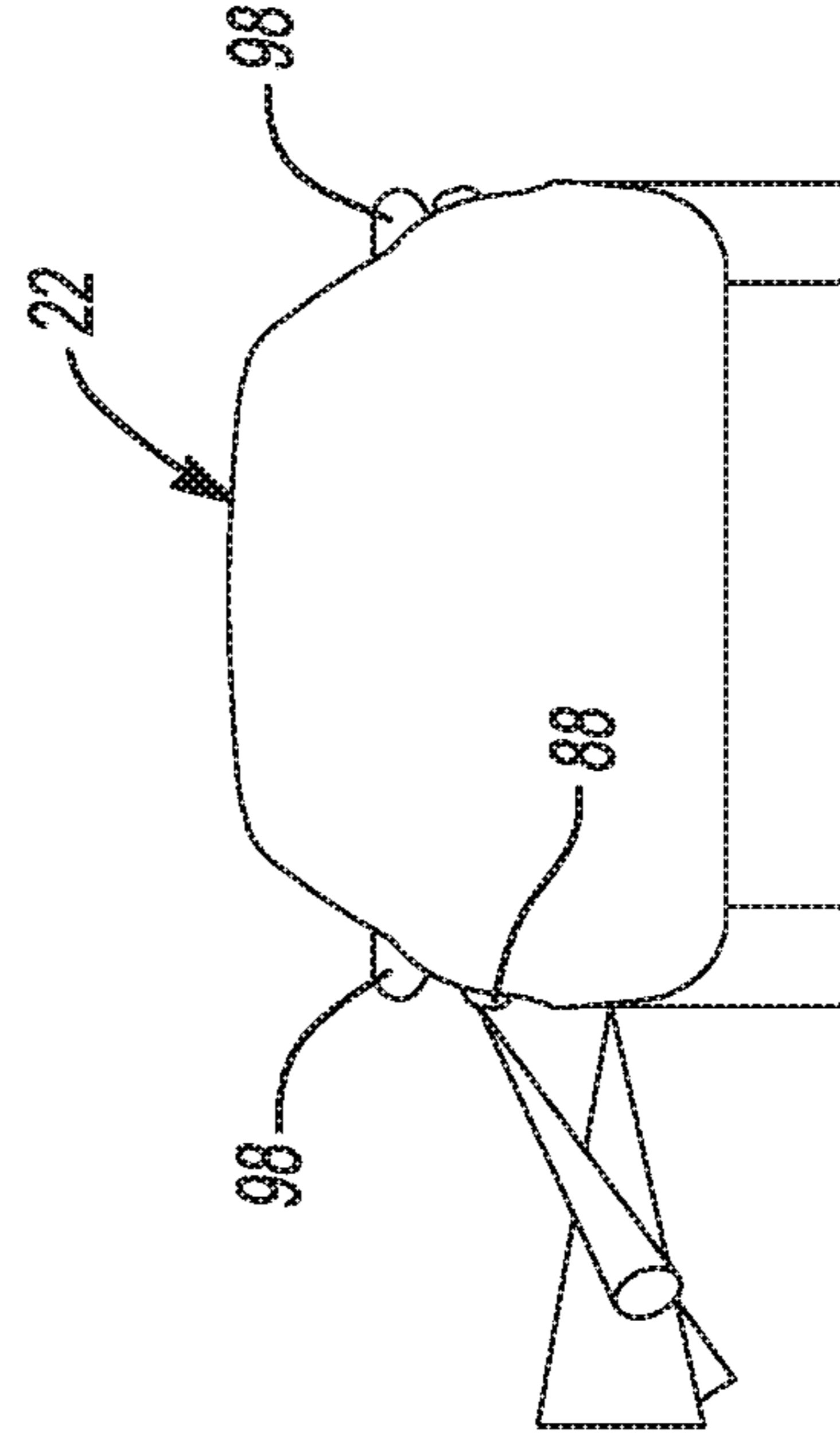


Fig-10D

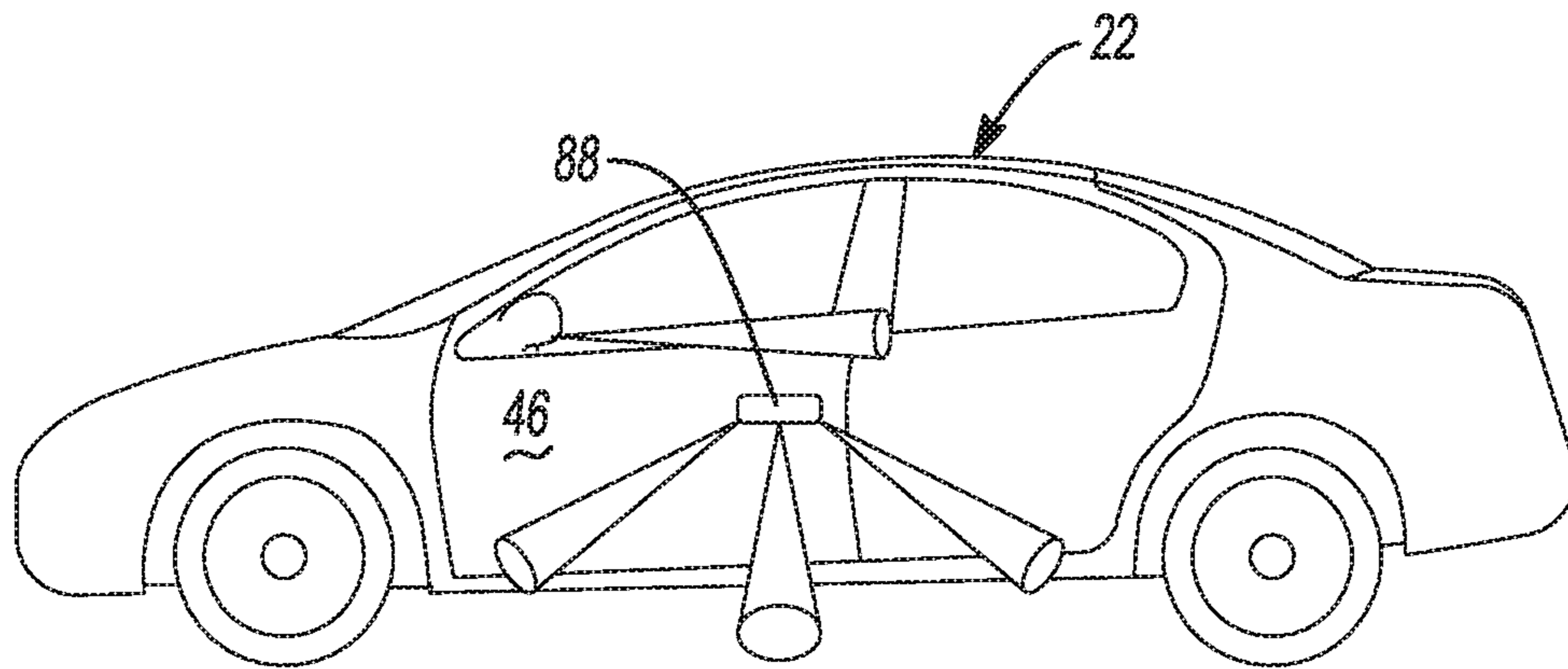


Fig-11A

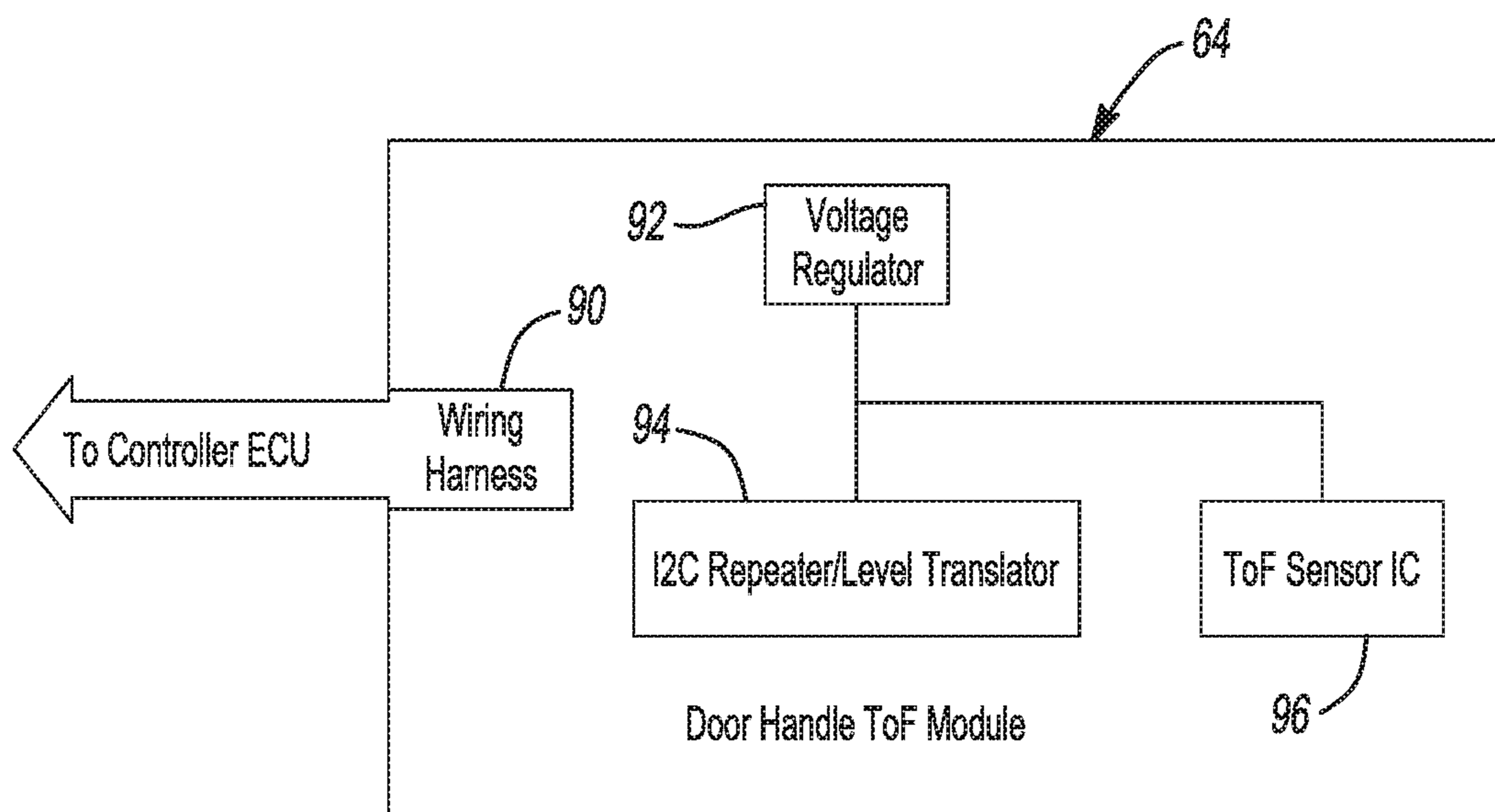


Fig-11B

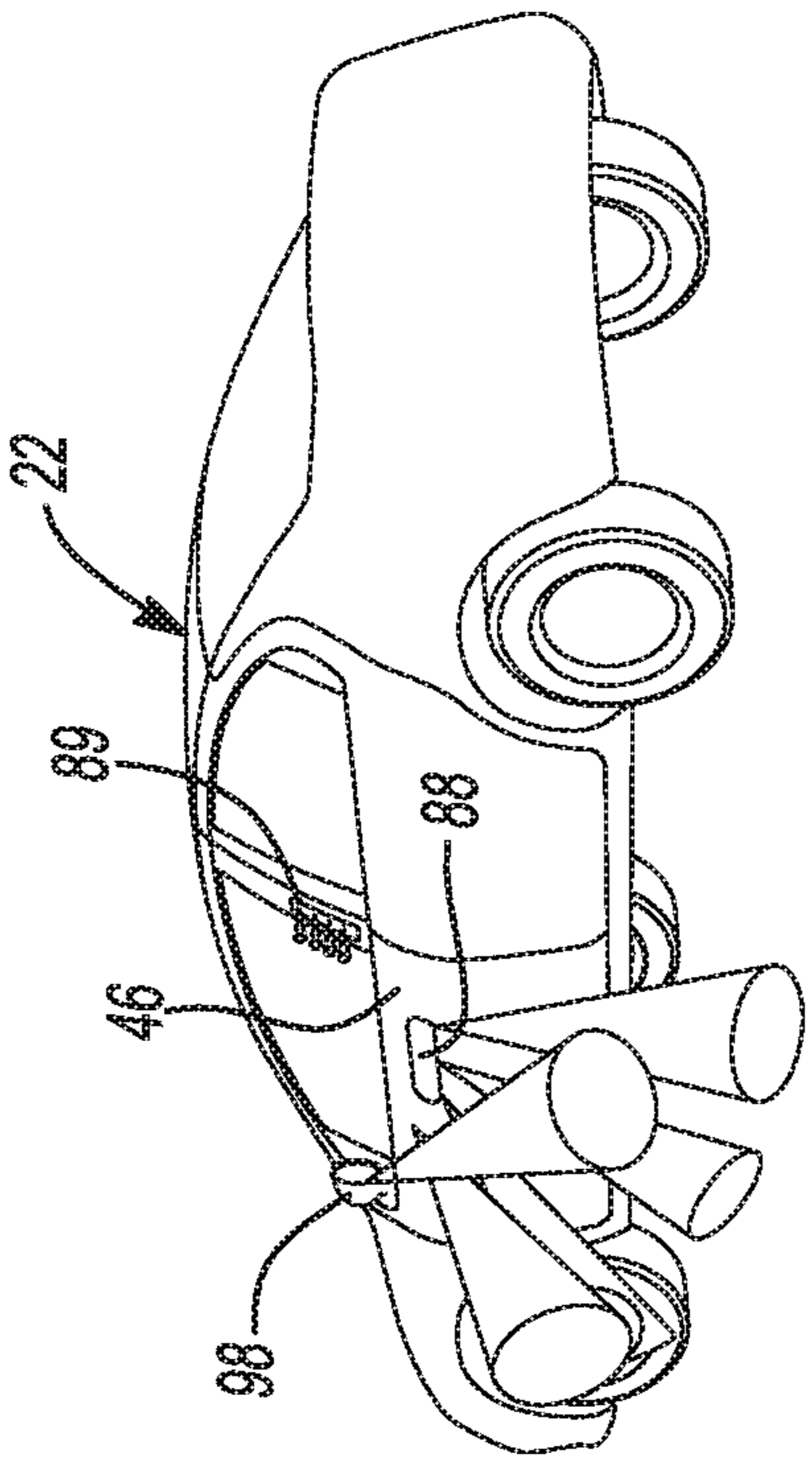


Fig-12A

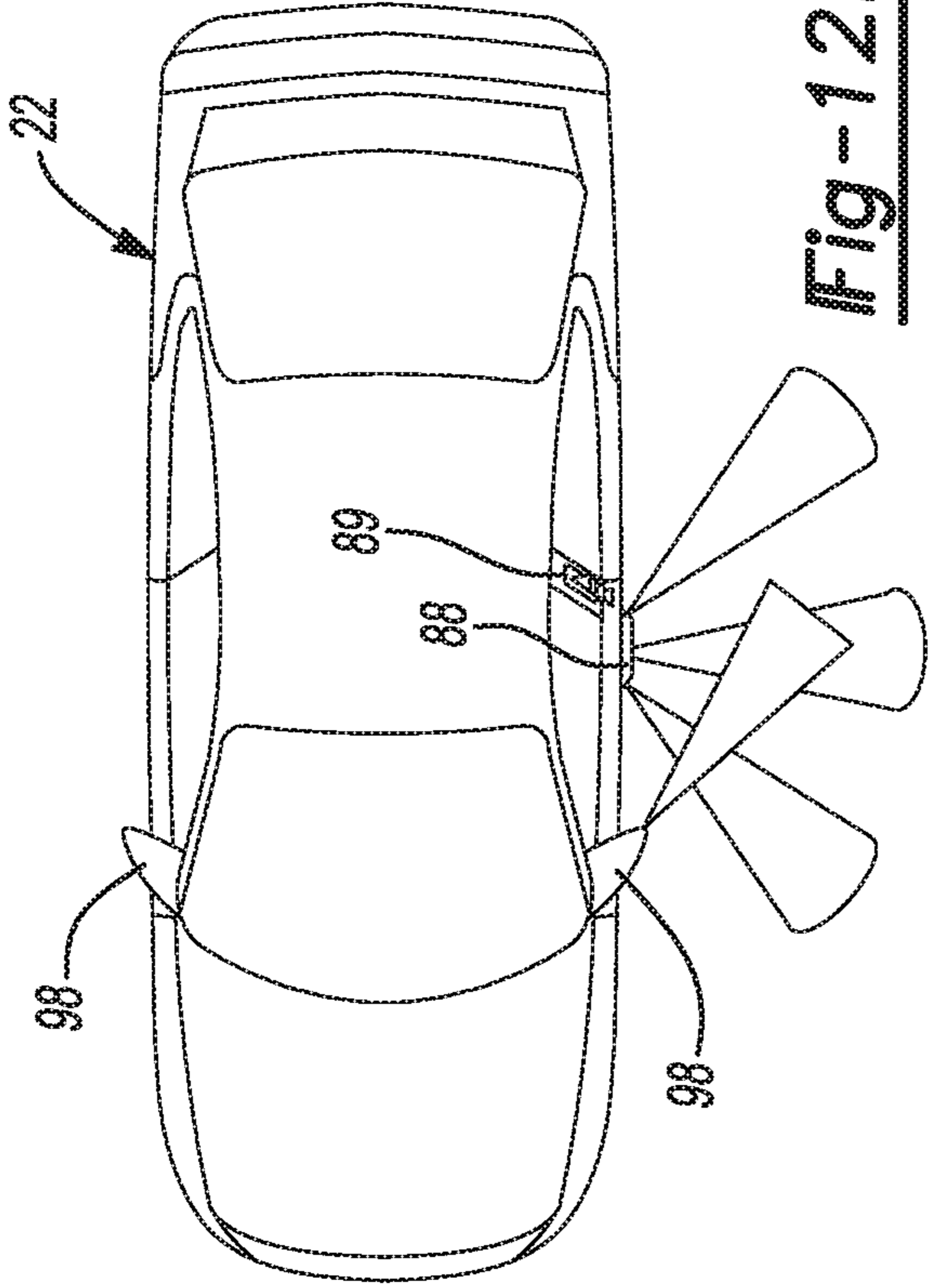


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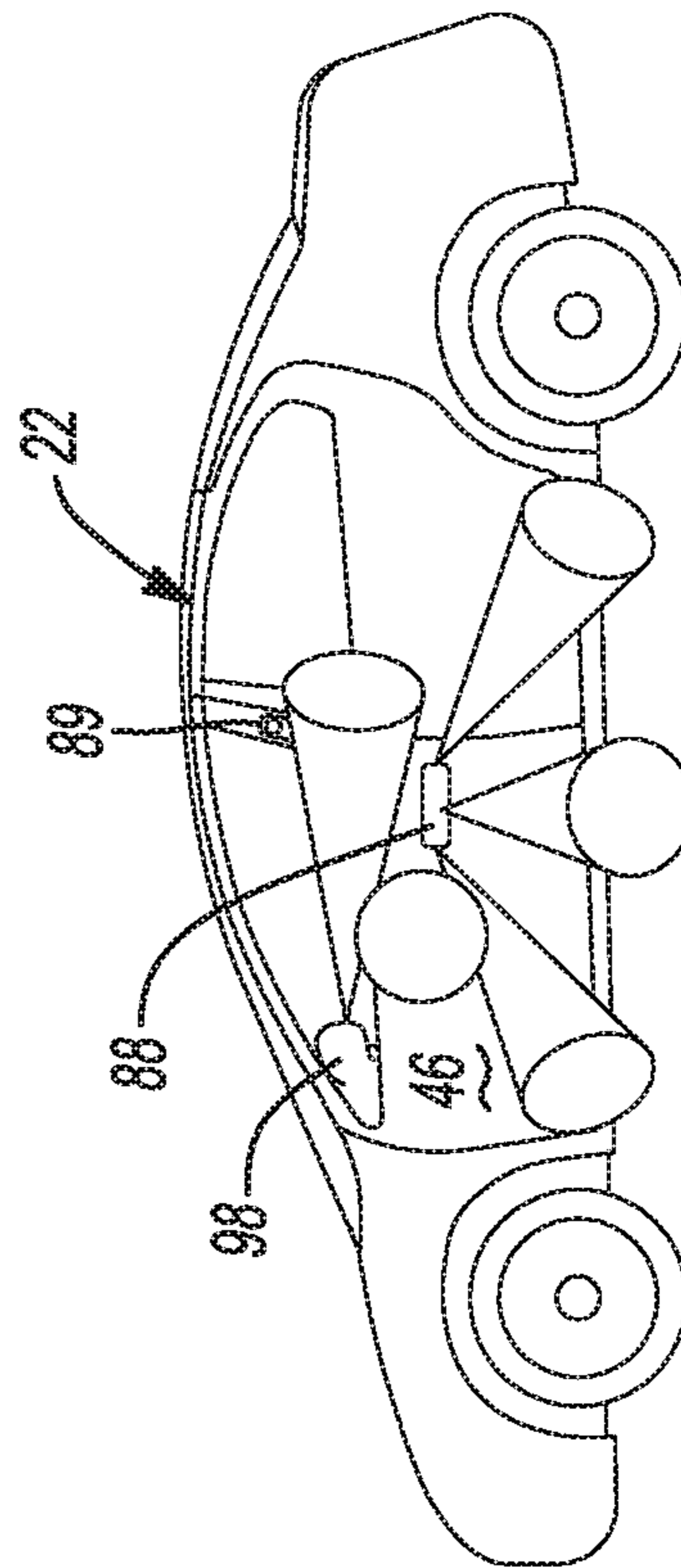


Fig-12C

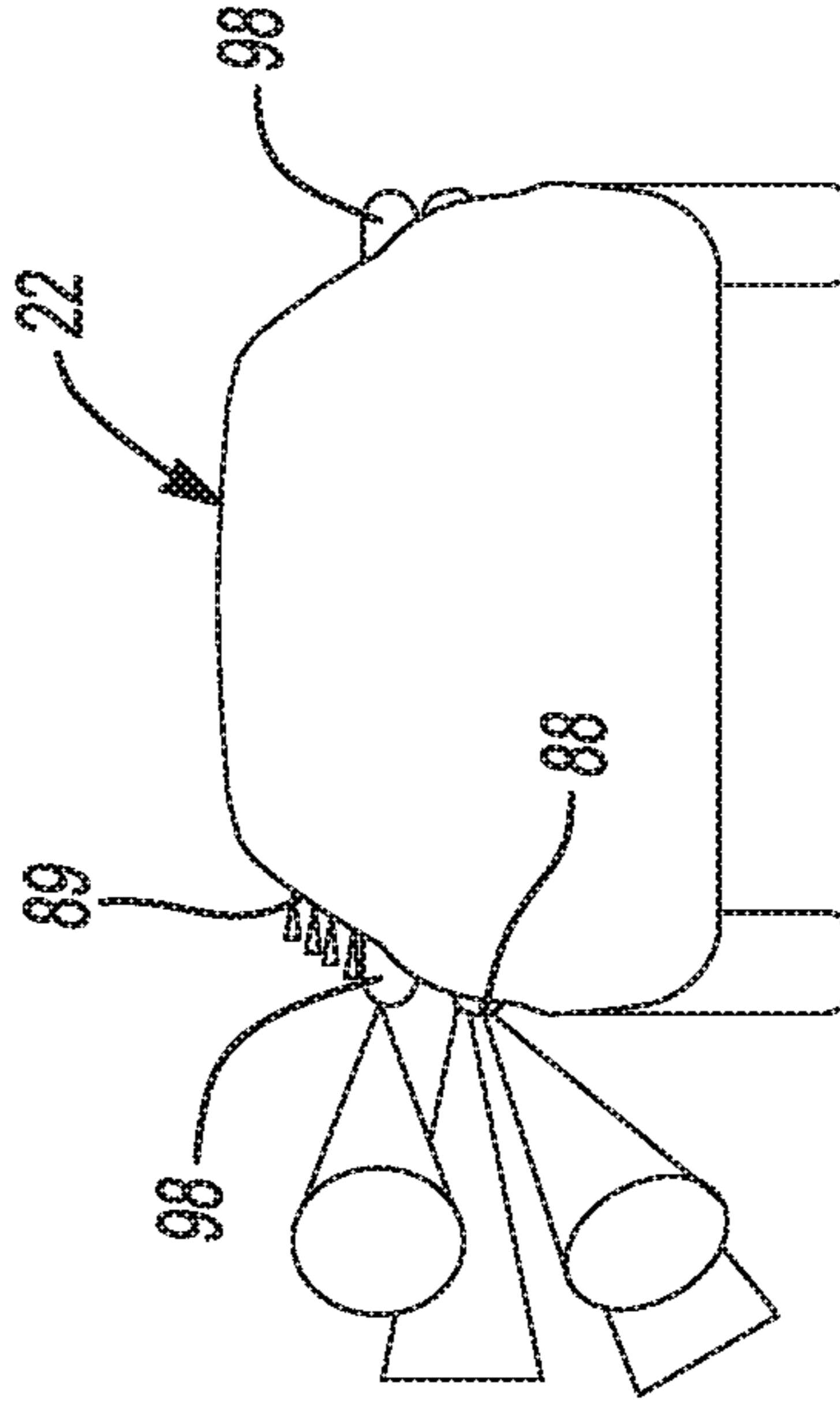


Fig-12D

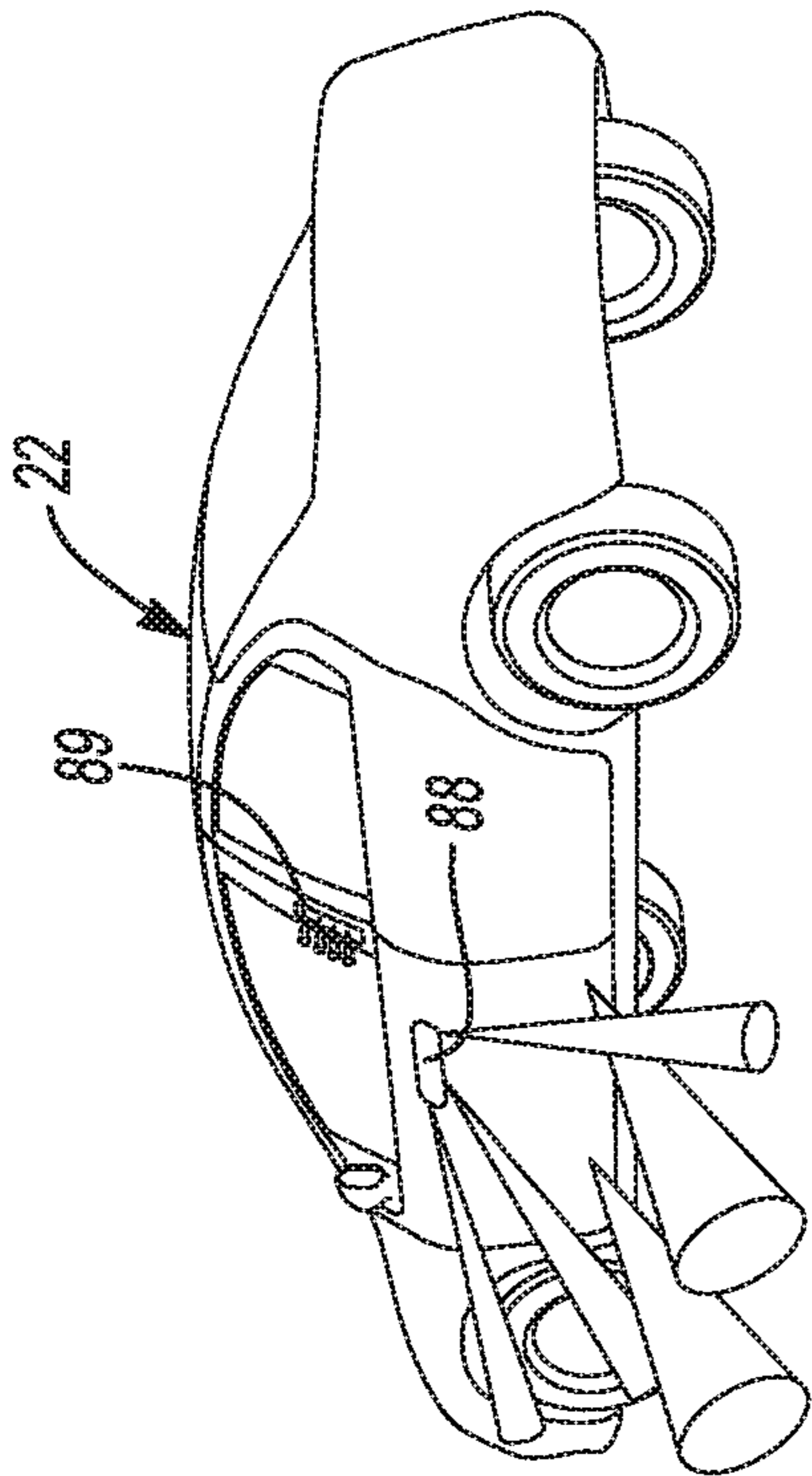


Fig-13A

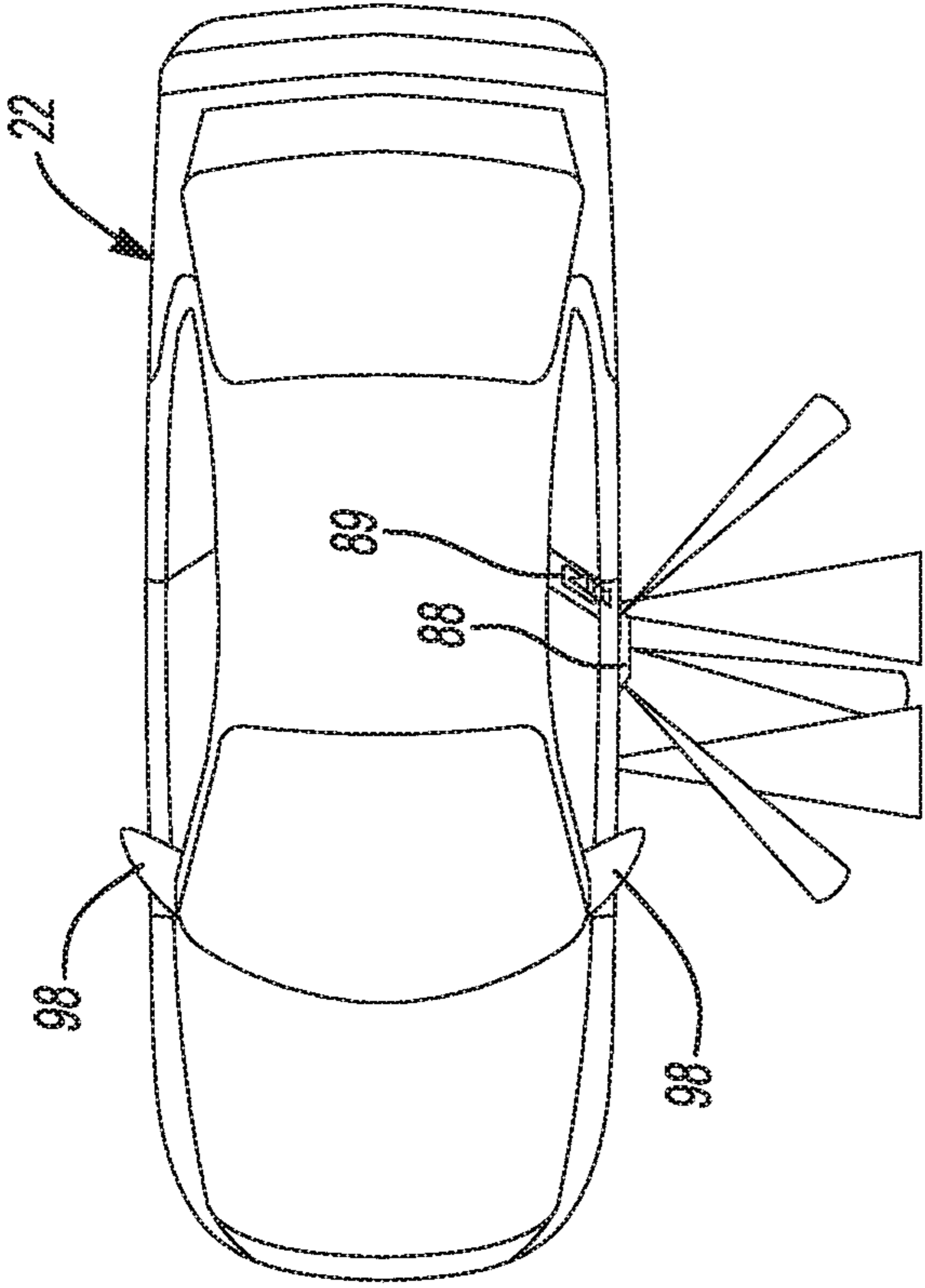


Fig-13B

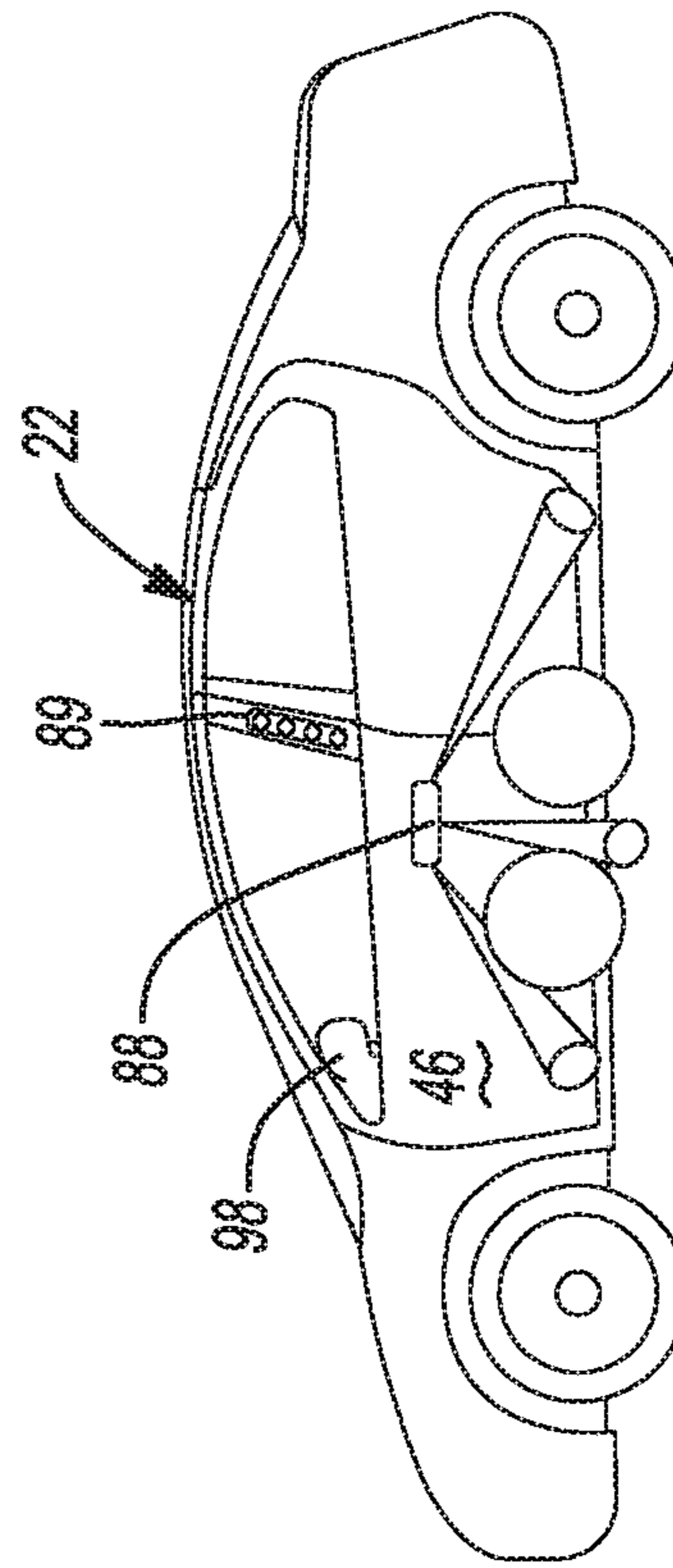


Fig-13C

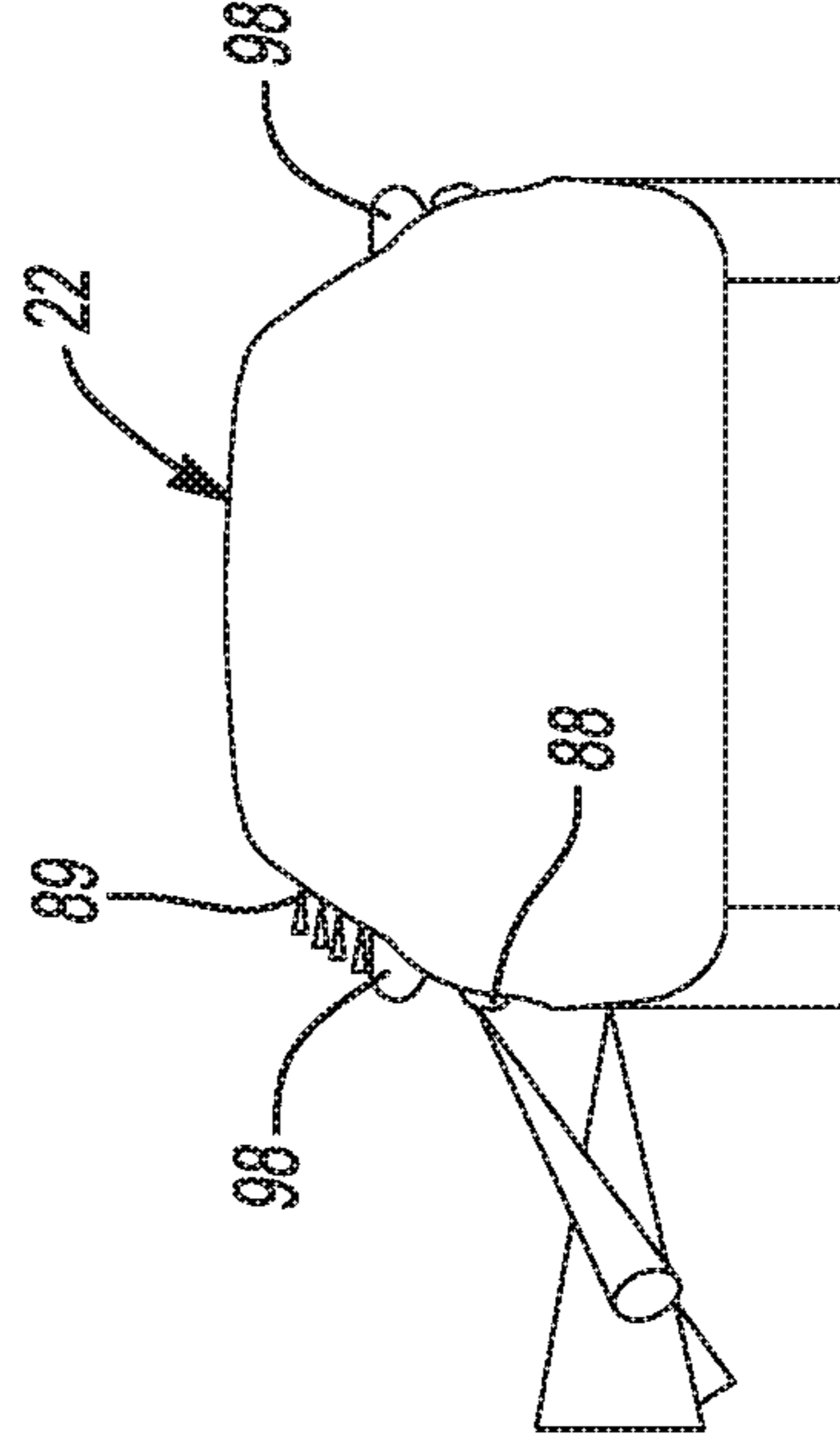


Fig-13D

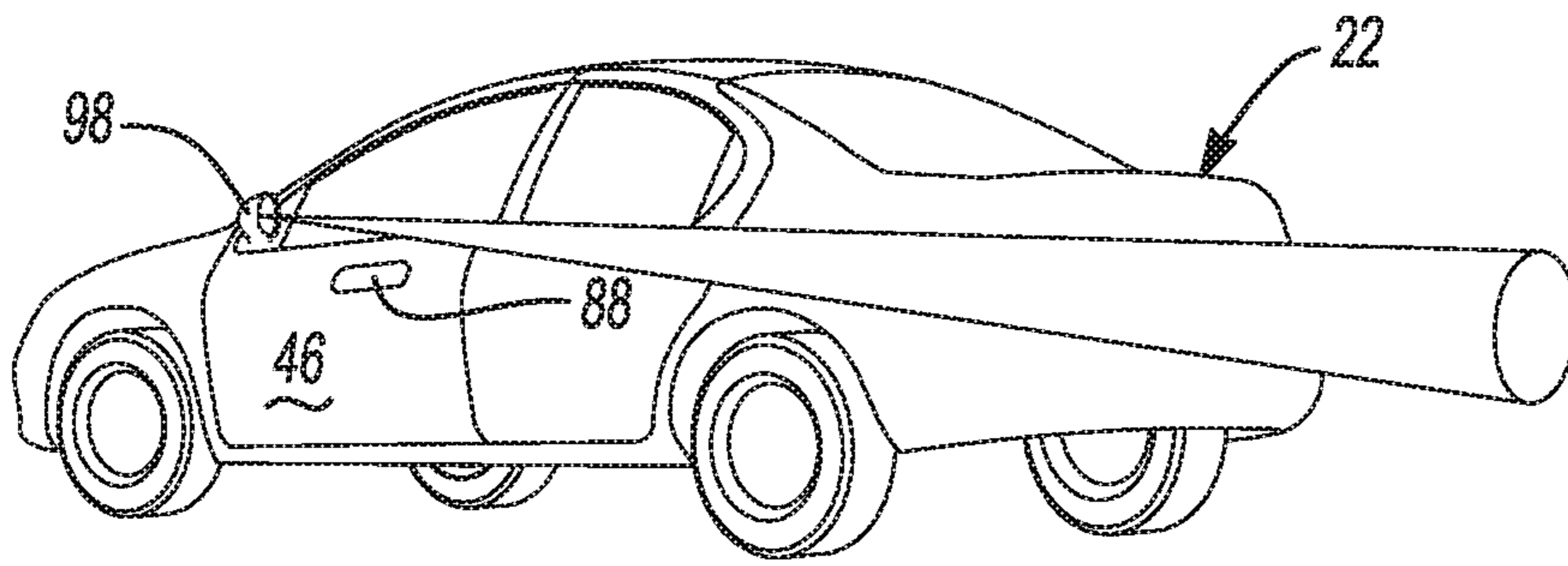


Fig-14A

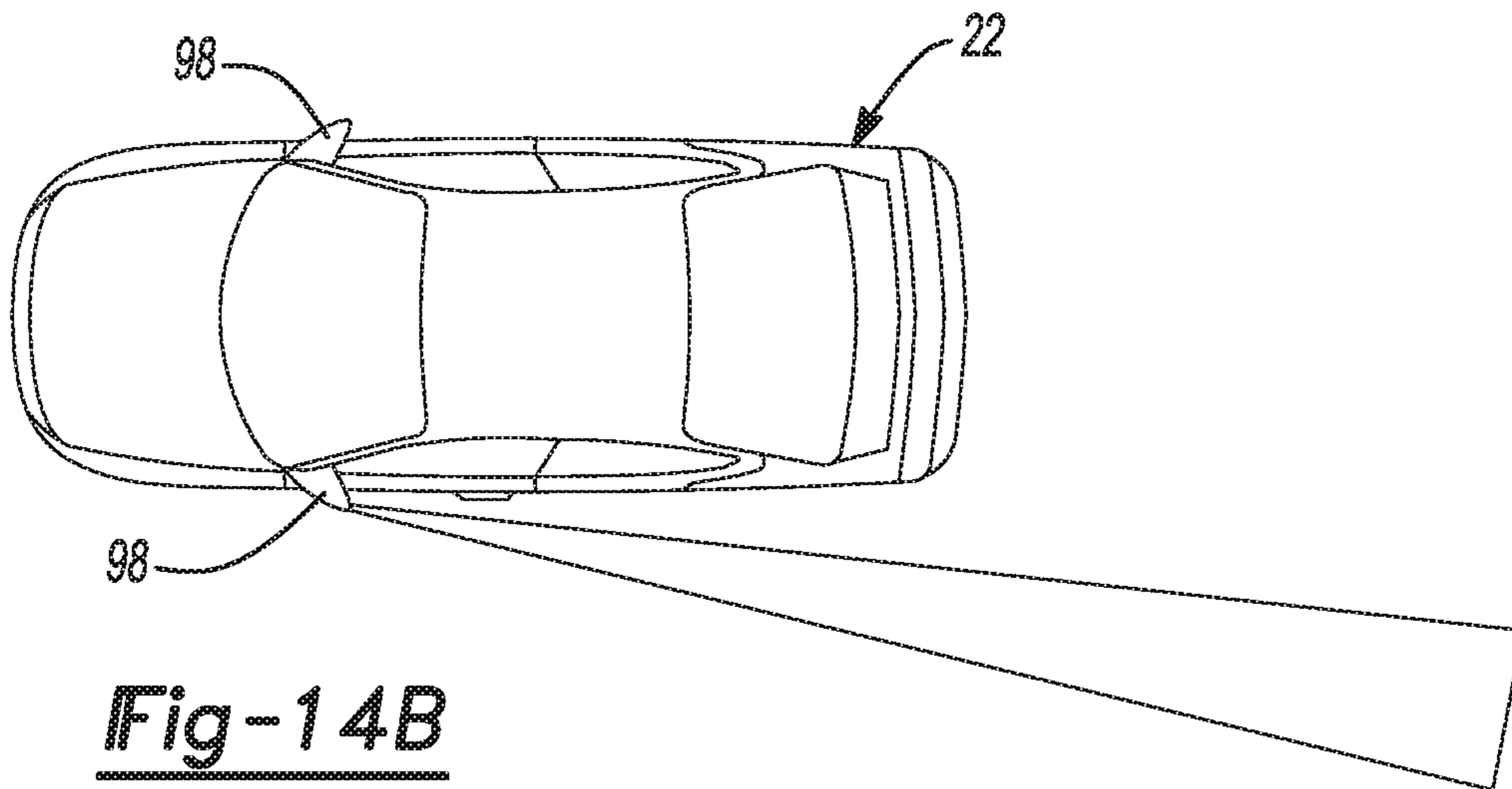


Fig-14B

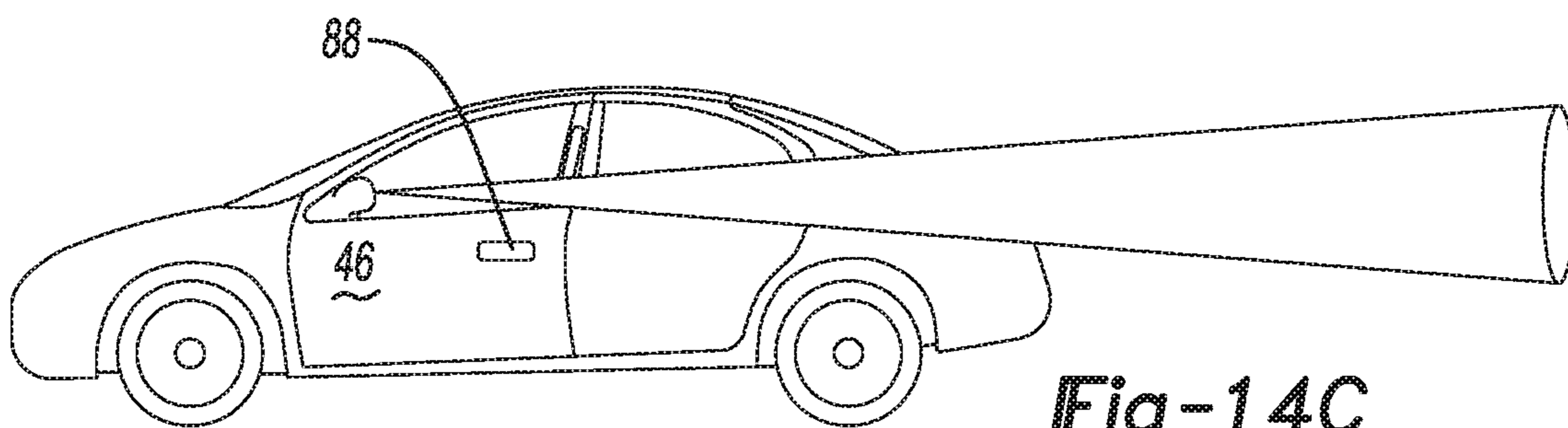


Fig-14C

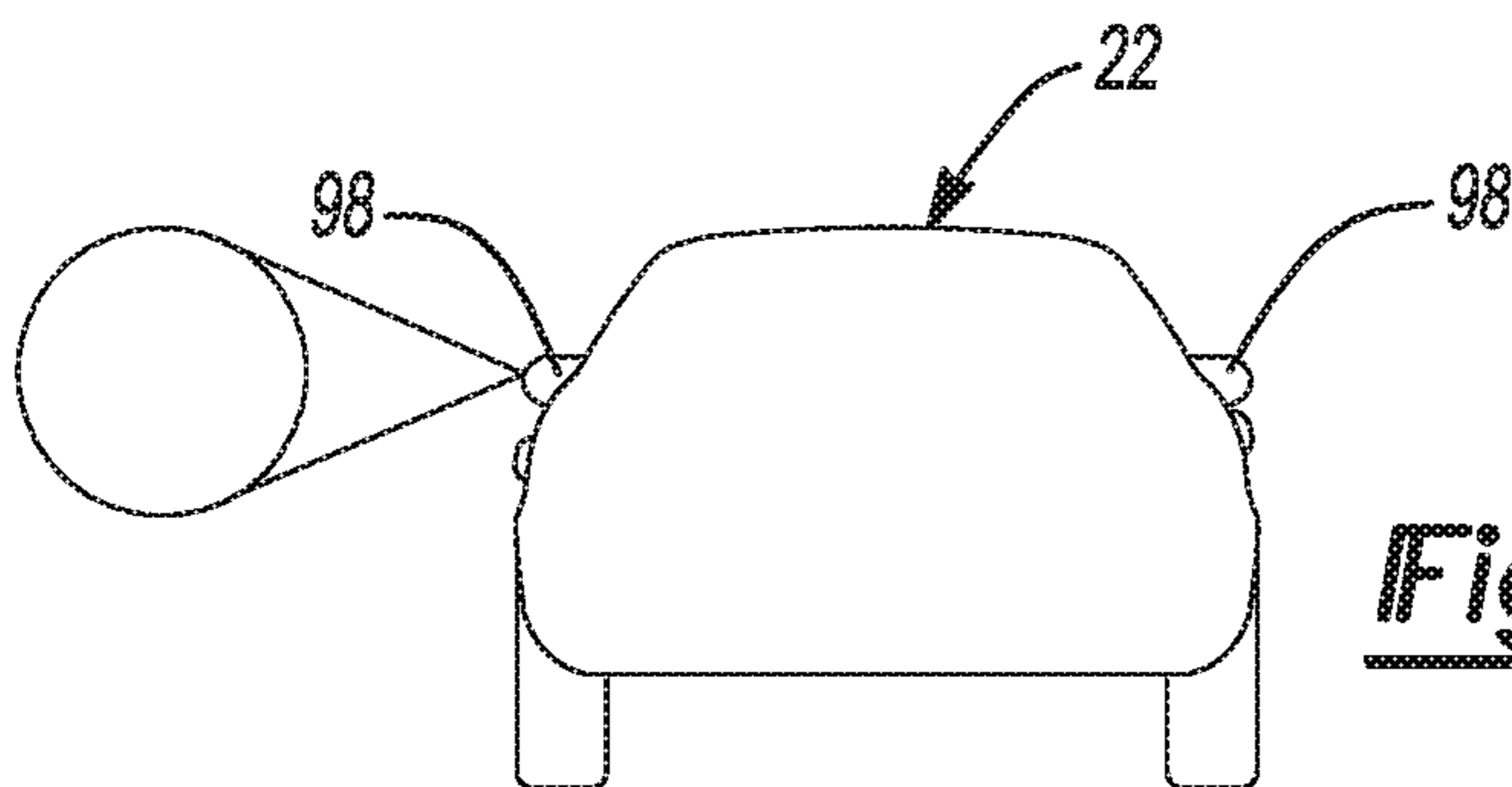


Fig-14D

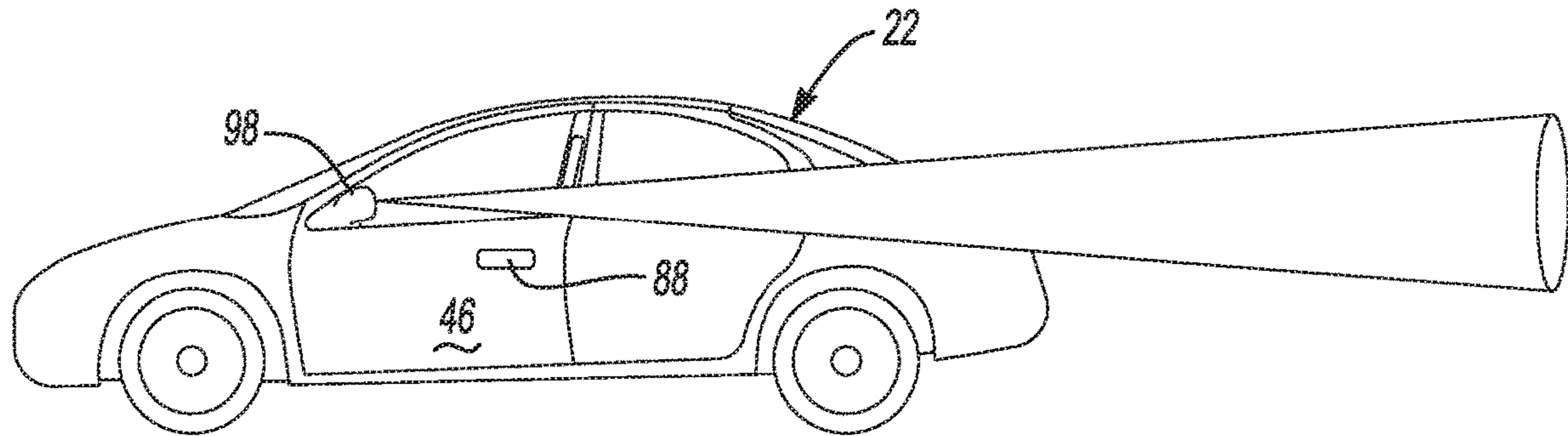


Fig-15A

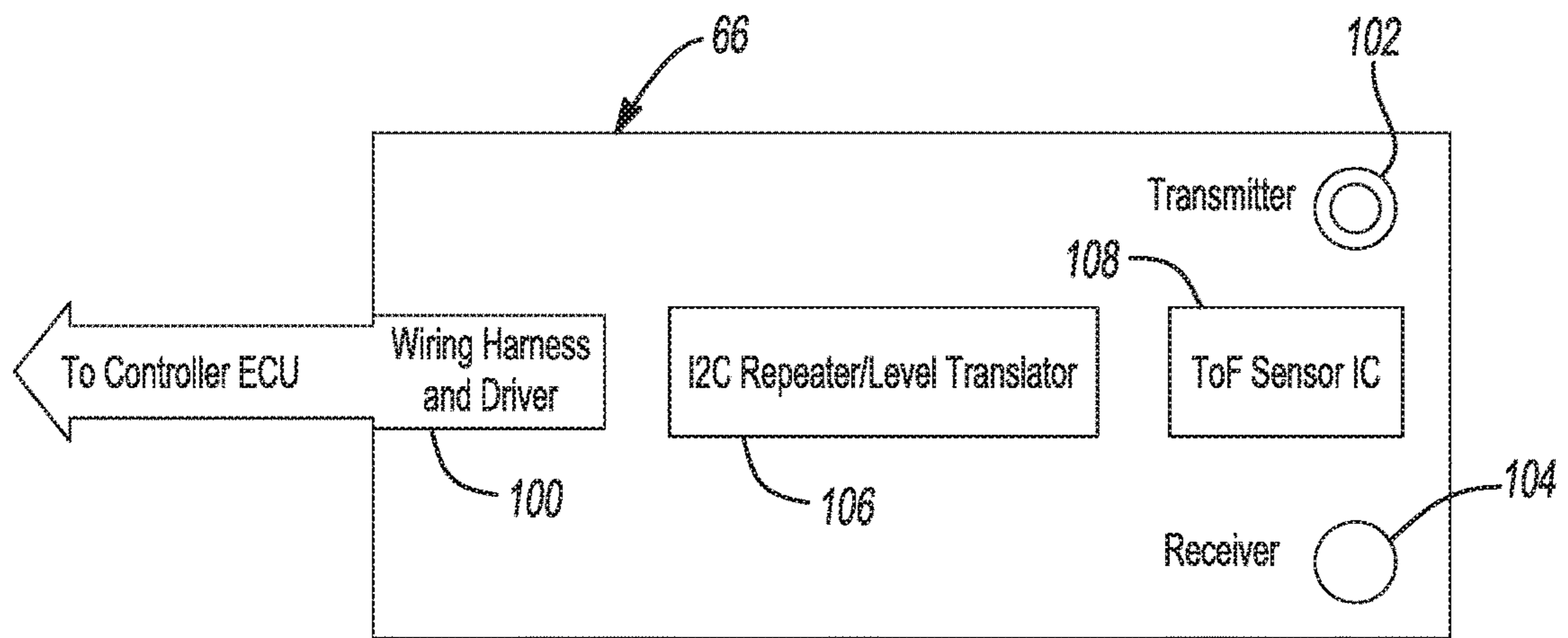
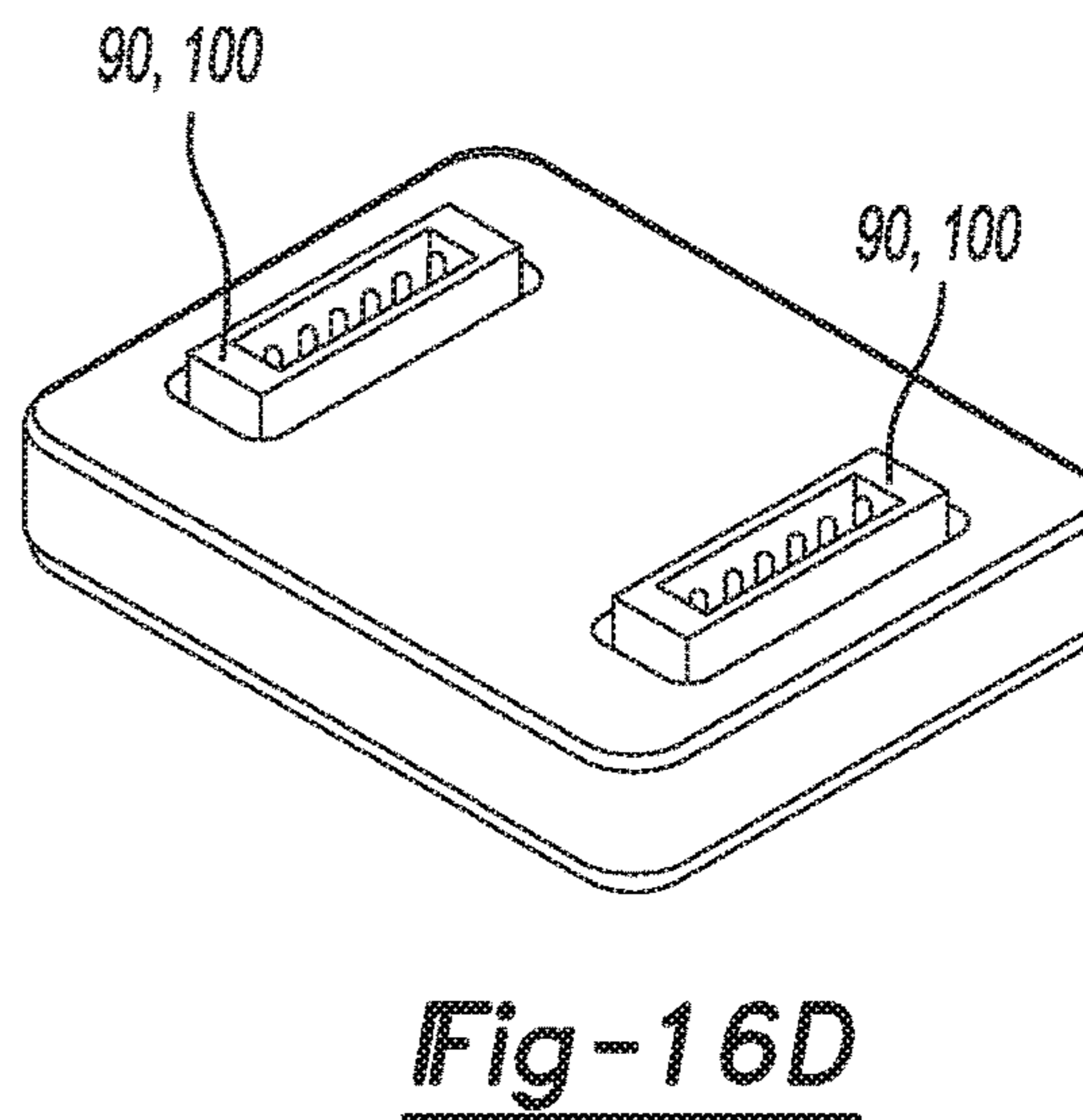
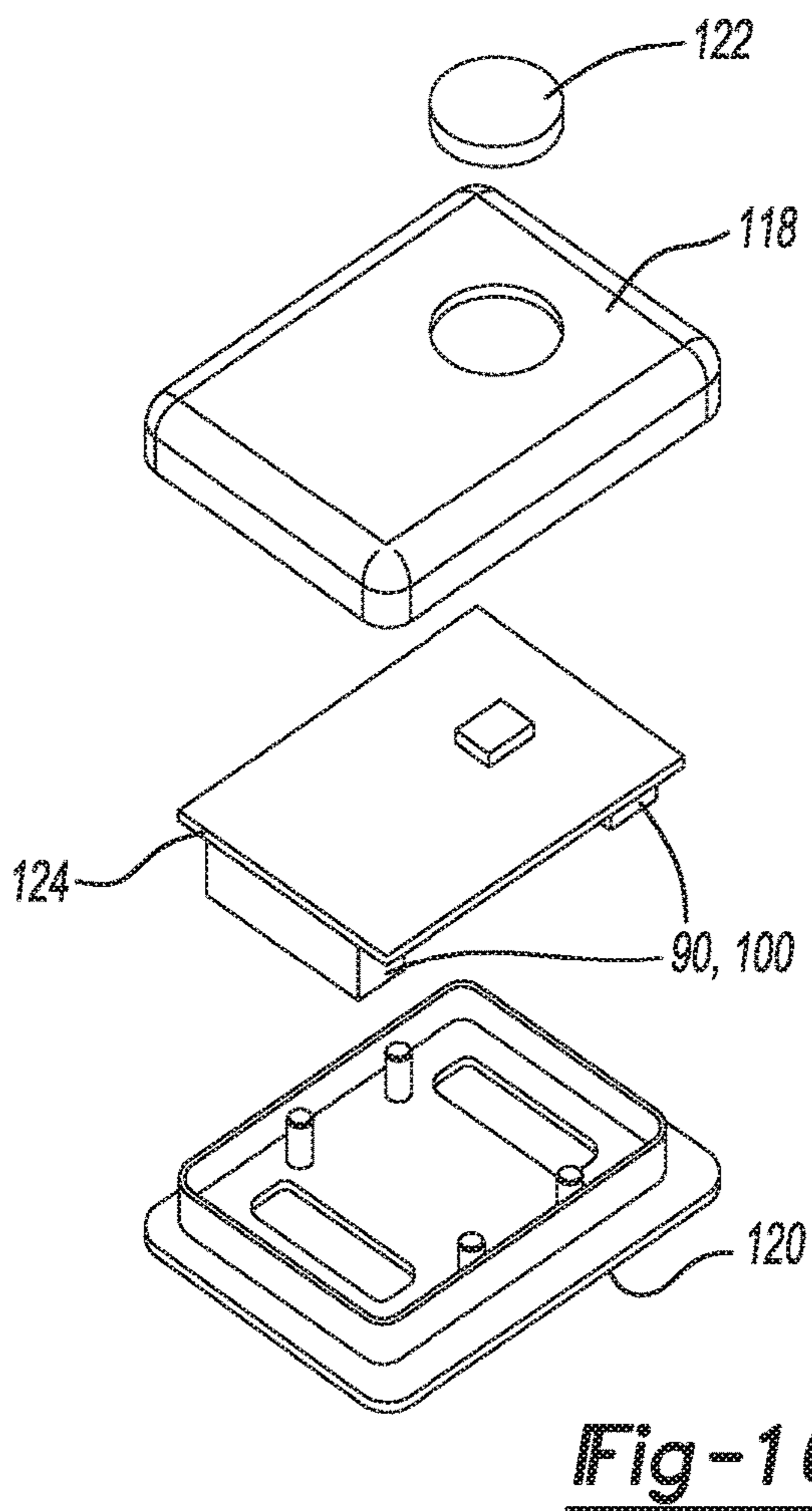
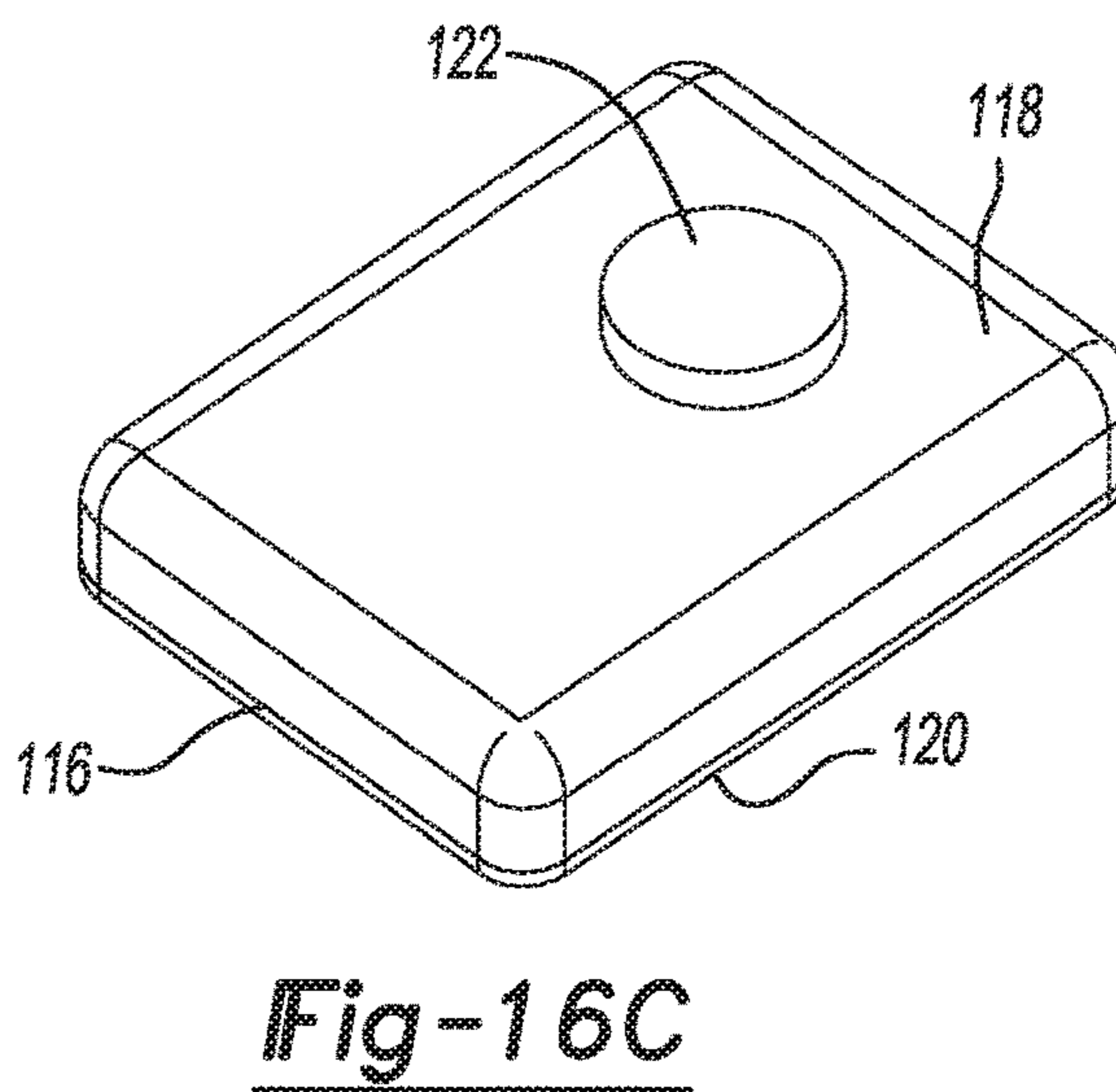
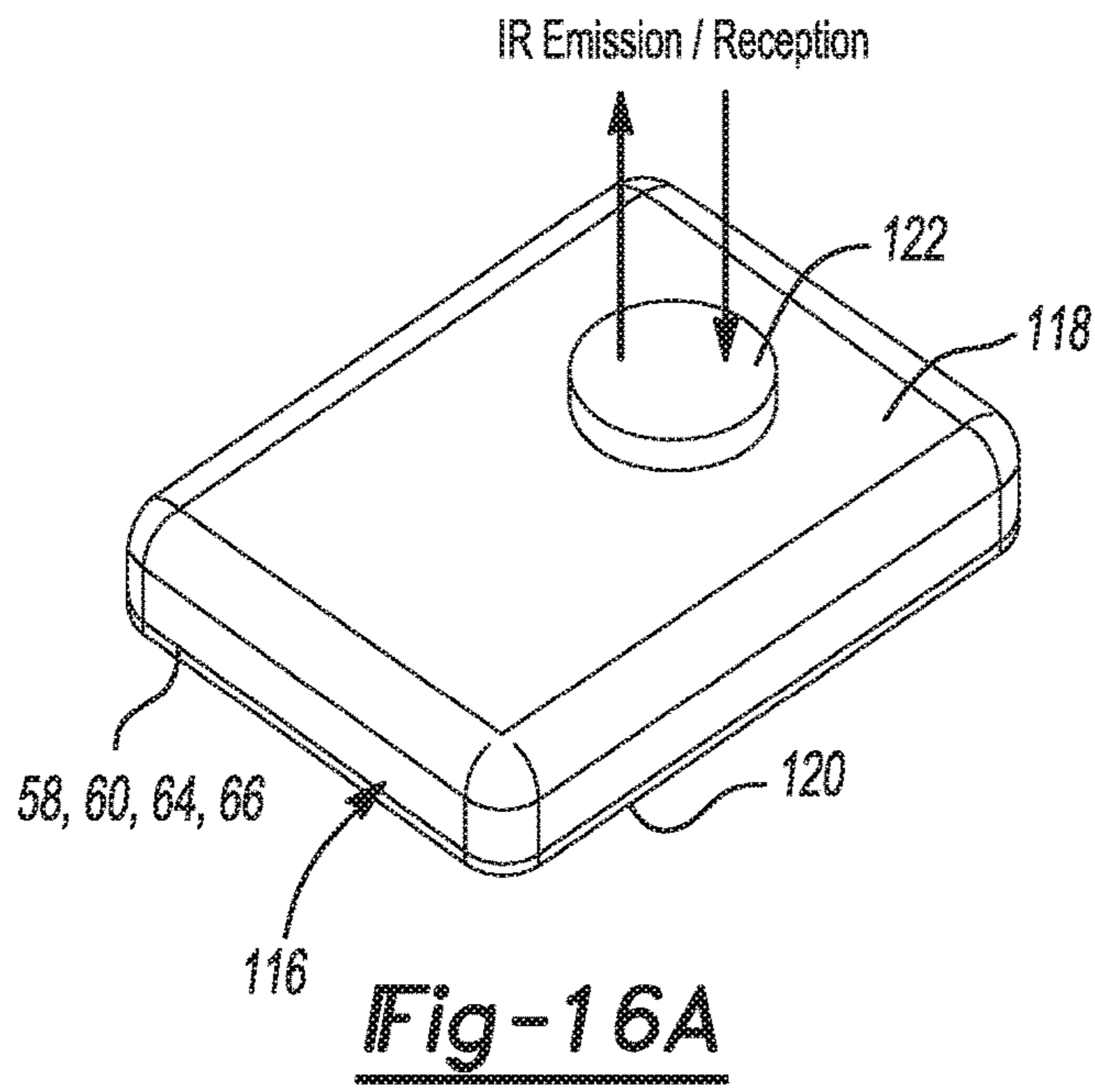
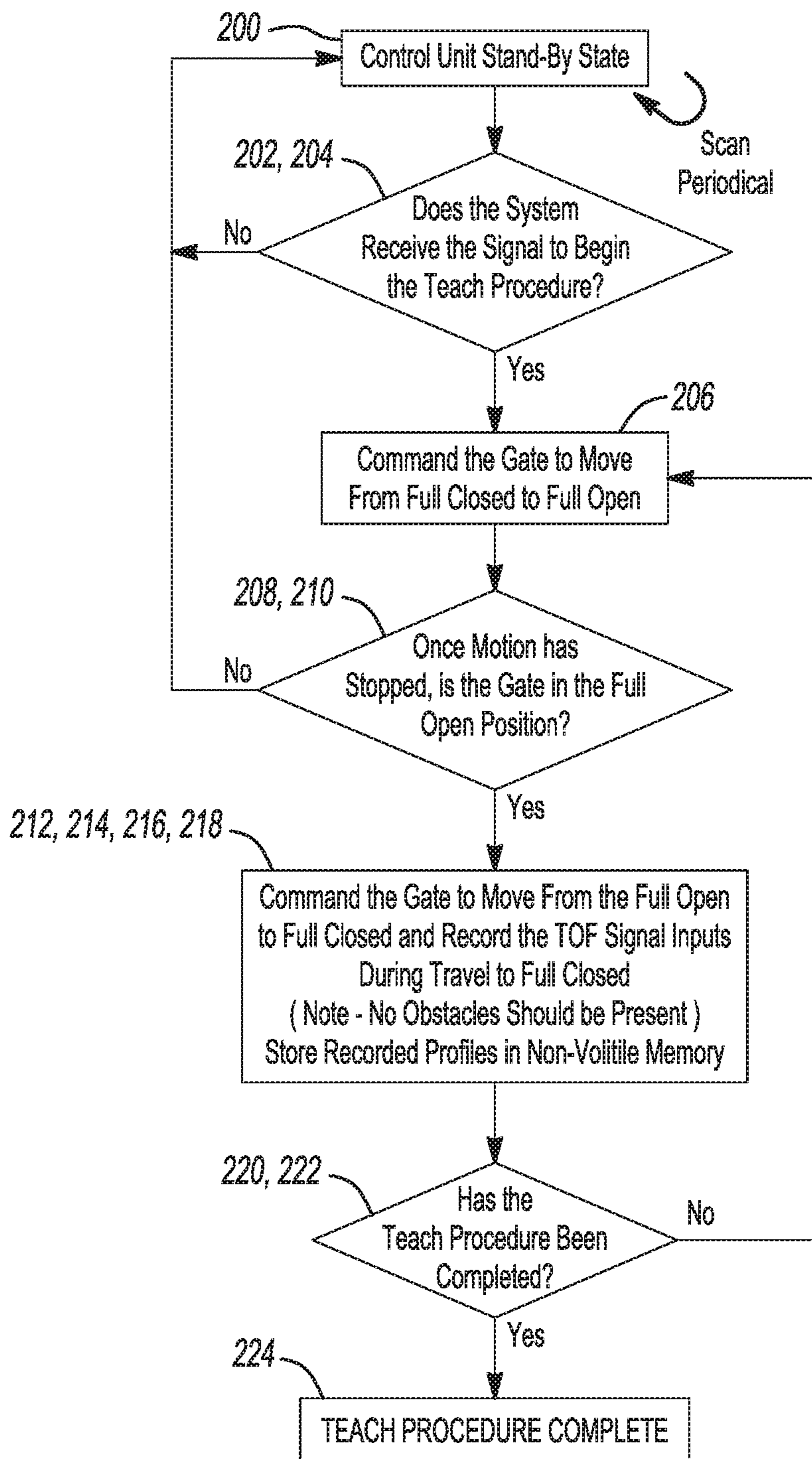


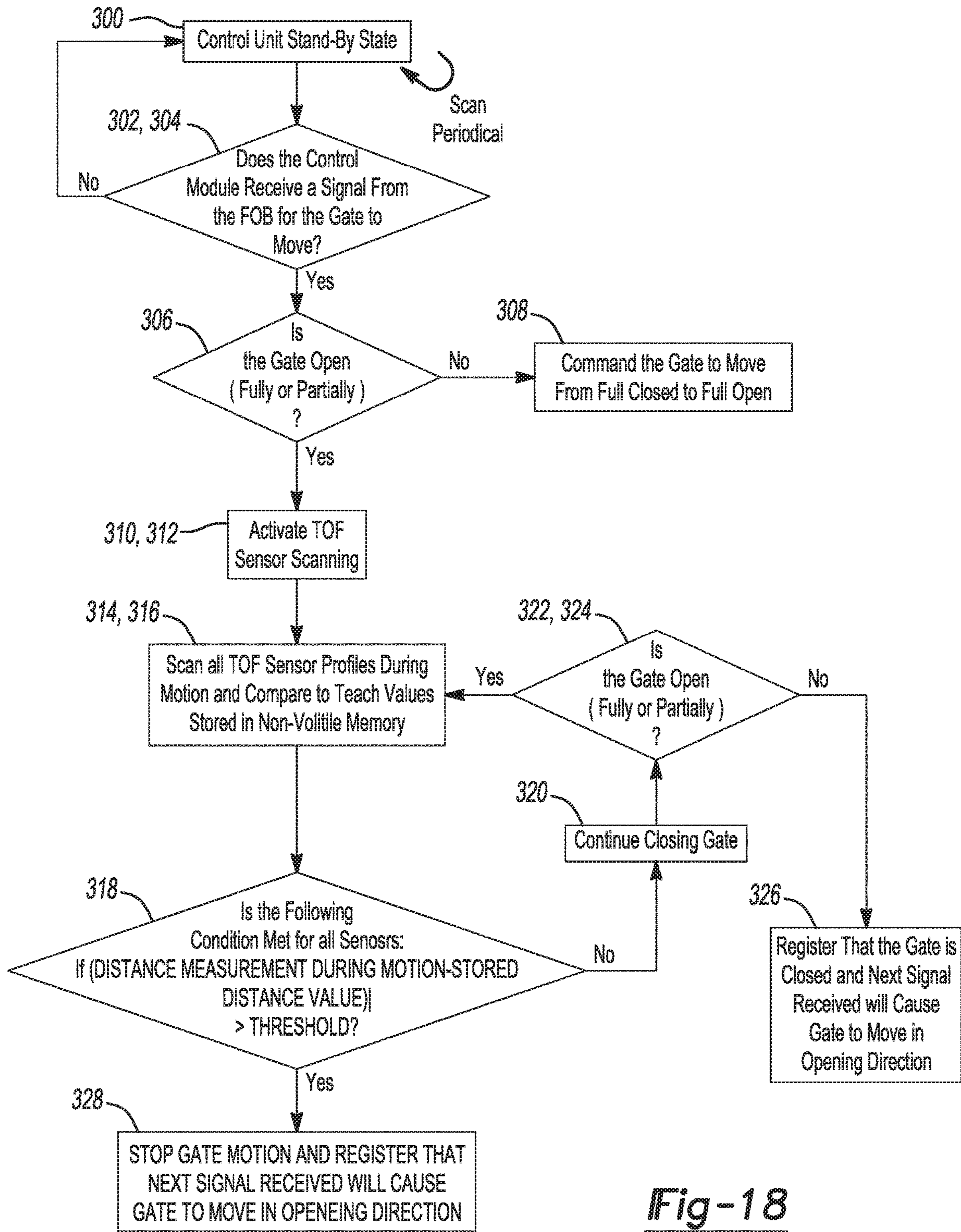
Fig-15B







*Fig-17*



**Fig-18**

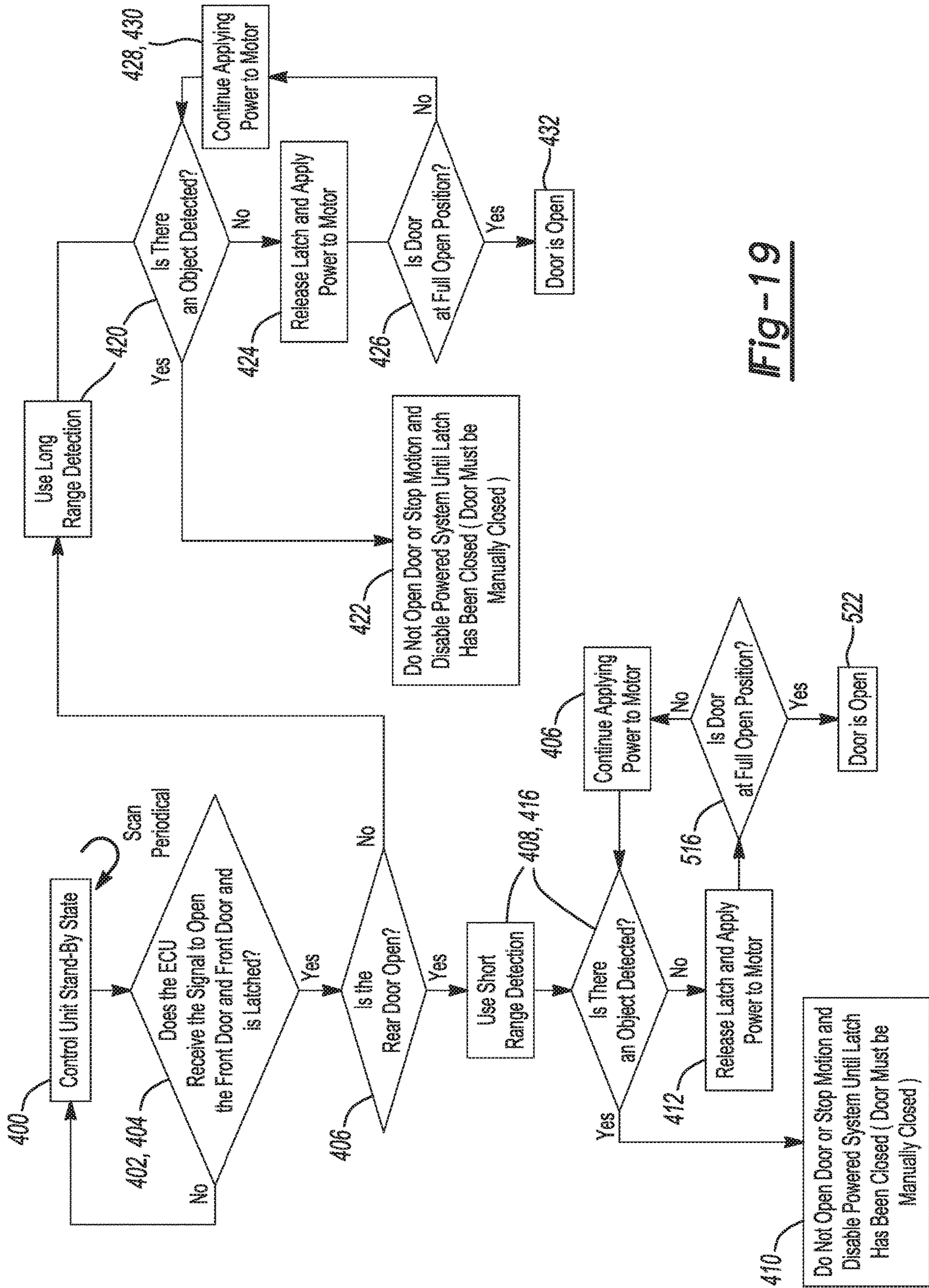
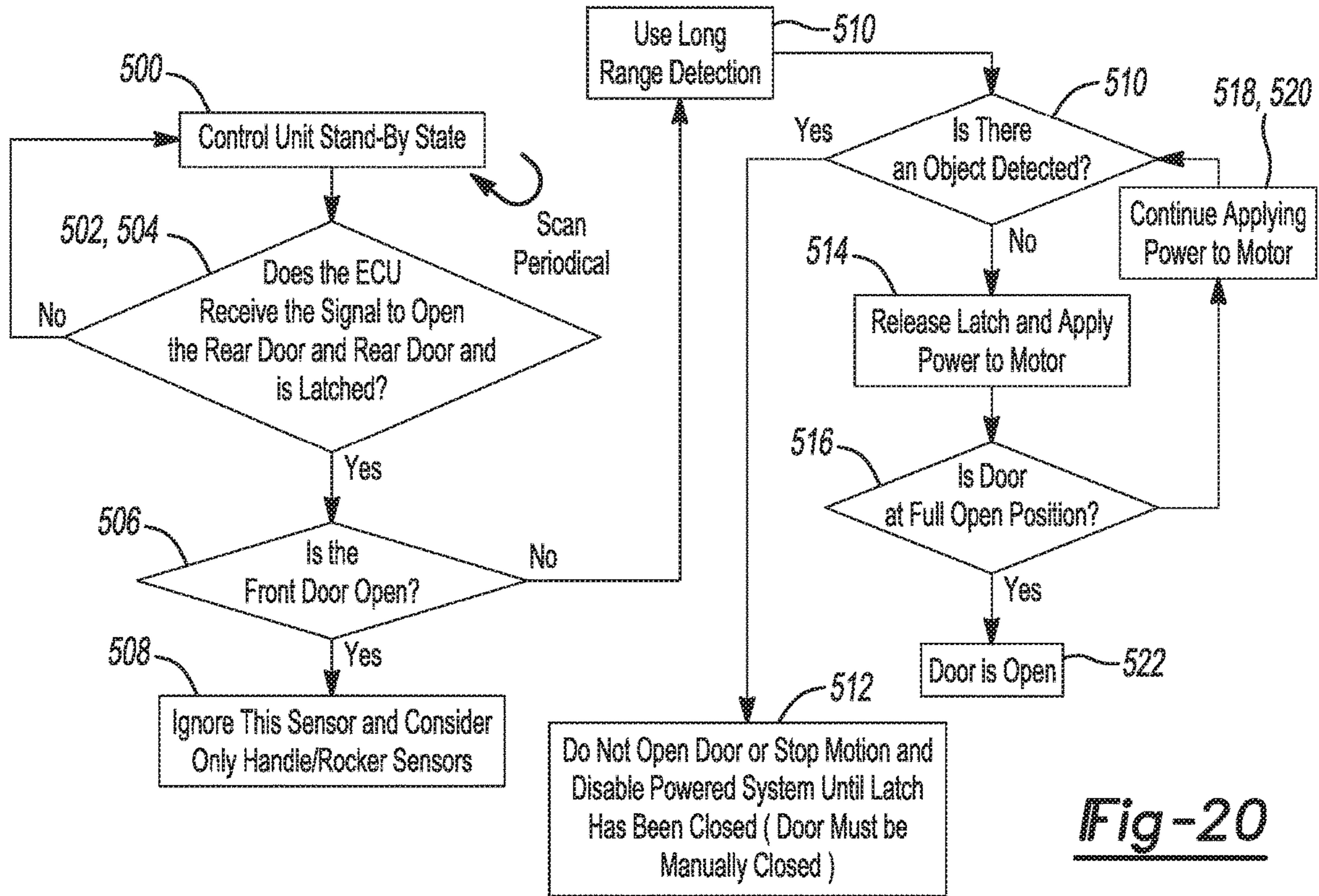
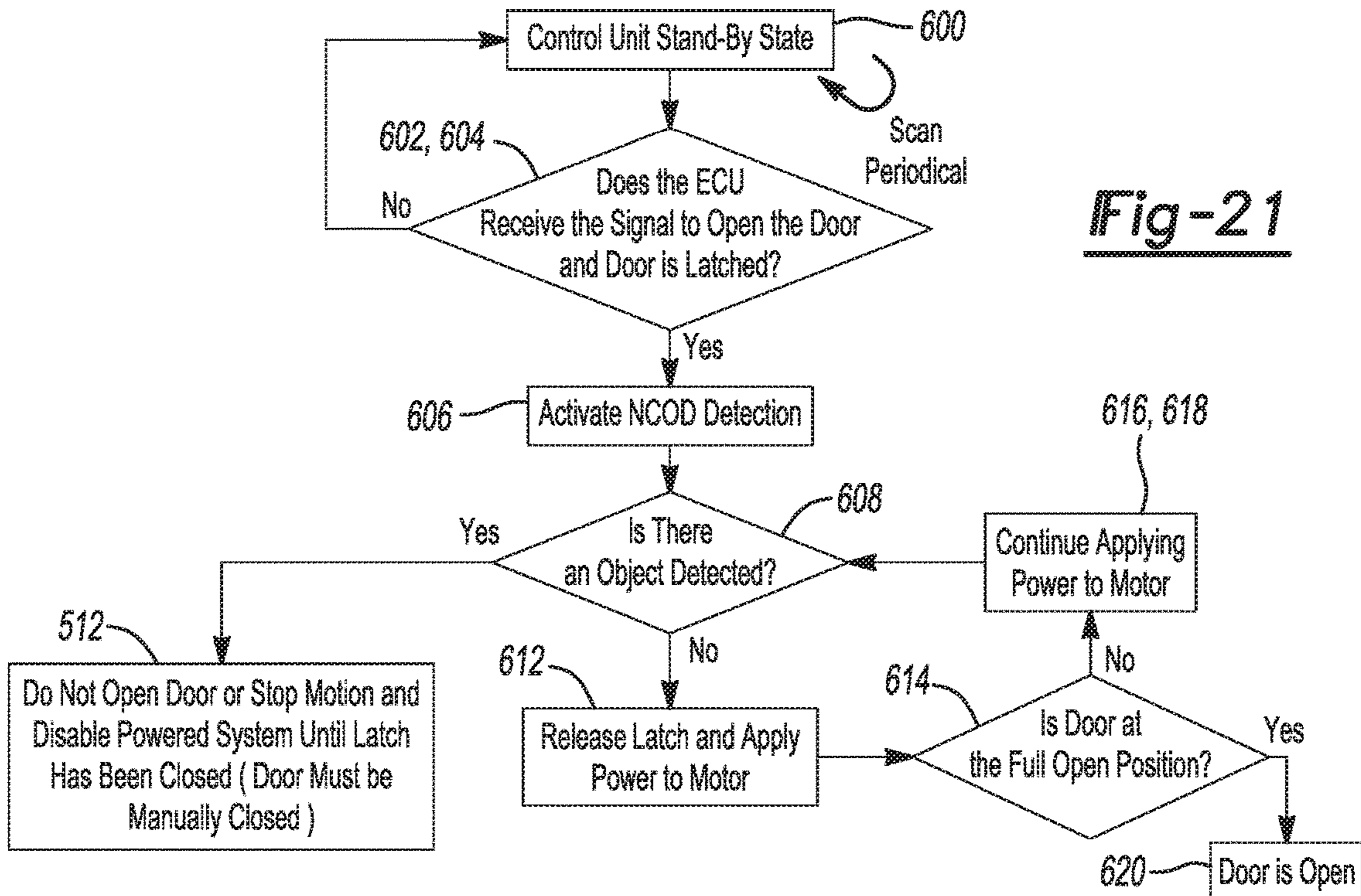


Fig-19



**Fig-20**



**Fig-21**

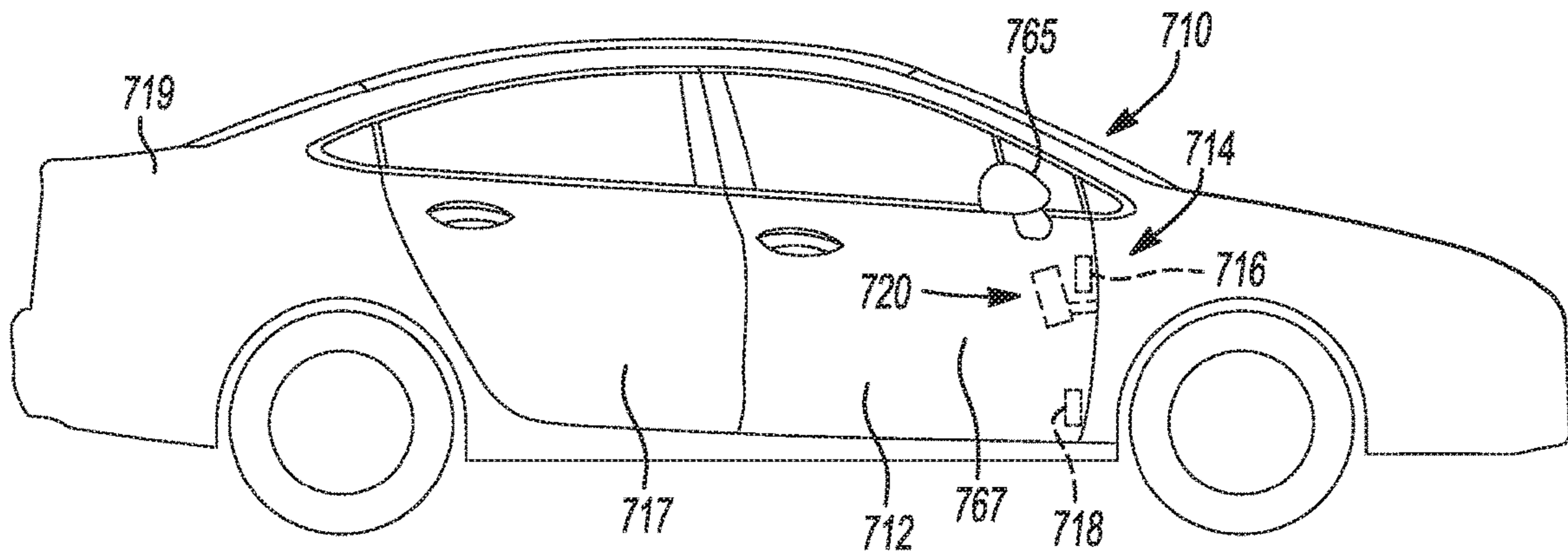


Fig-22

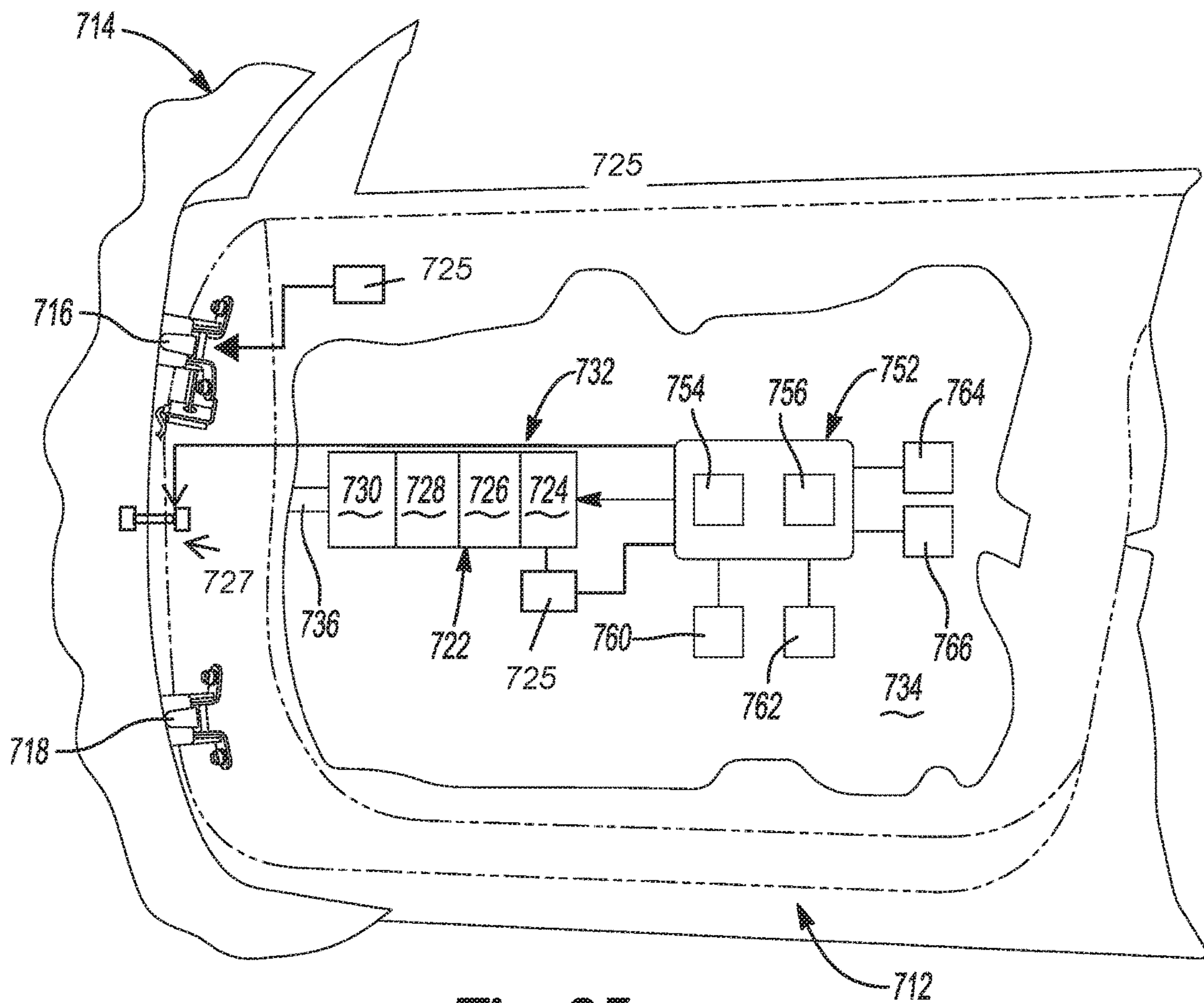


Fig-23

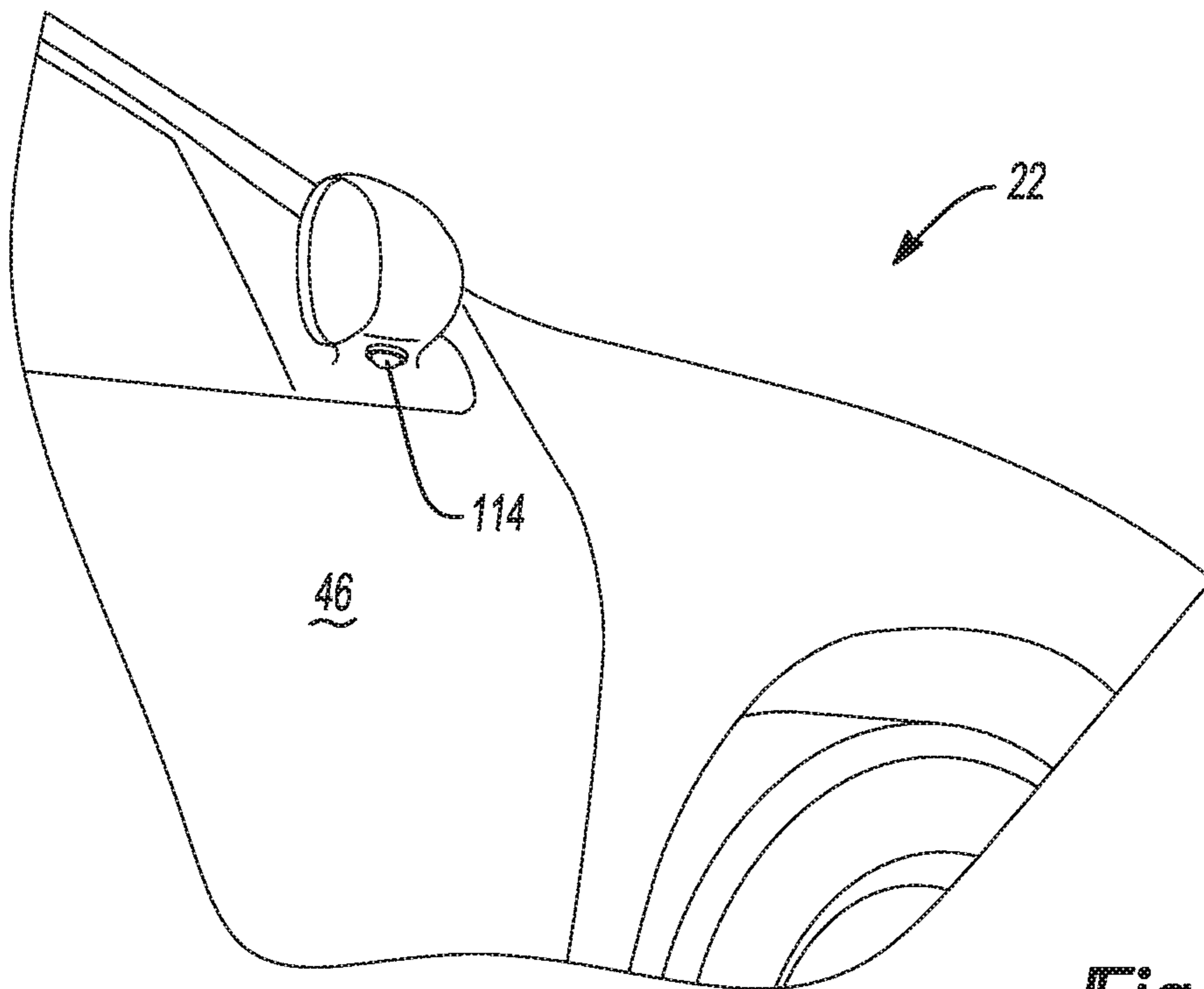


Fig-24A

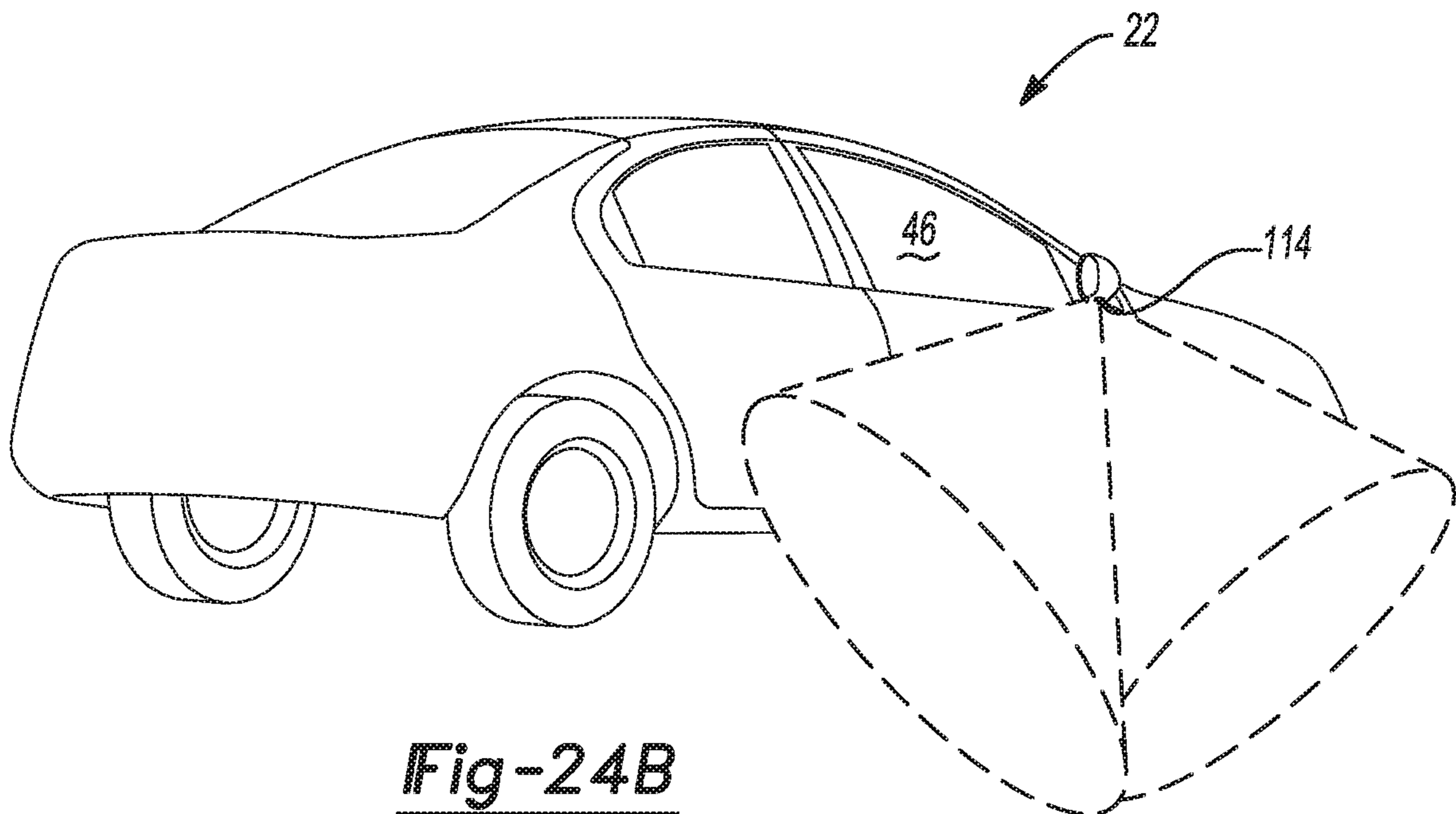
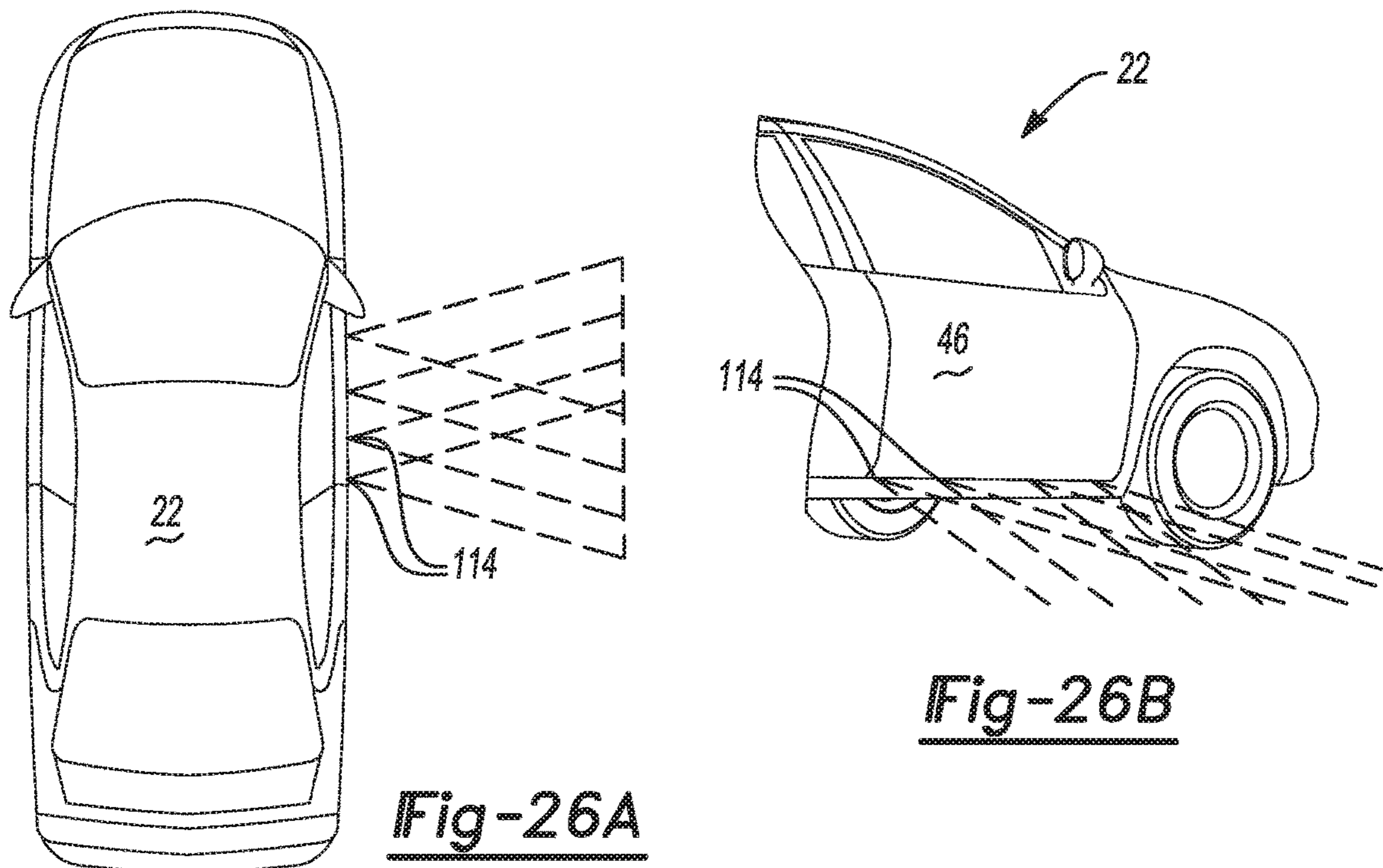
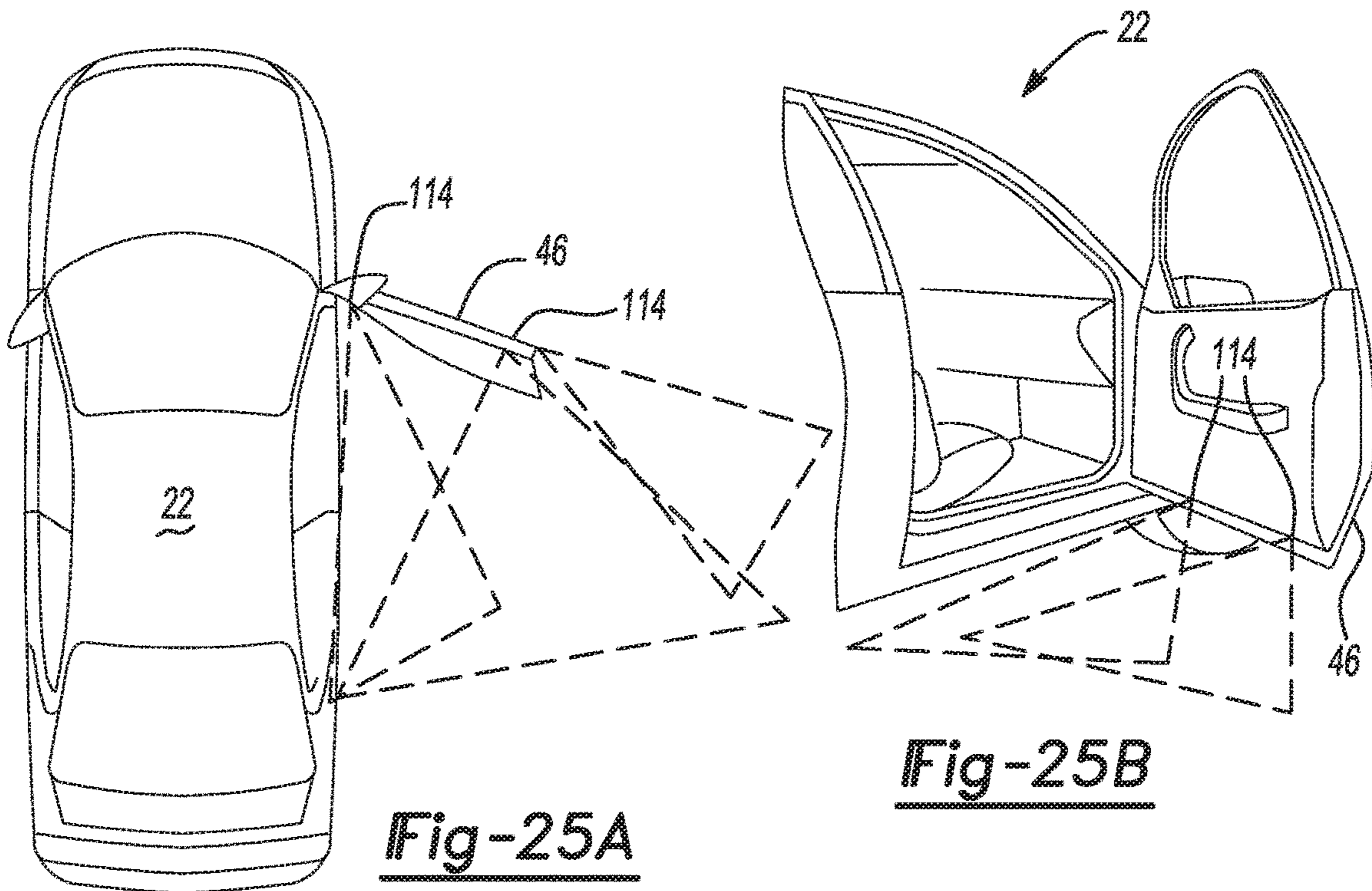


Fig-24B



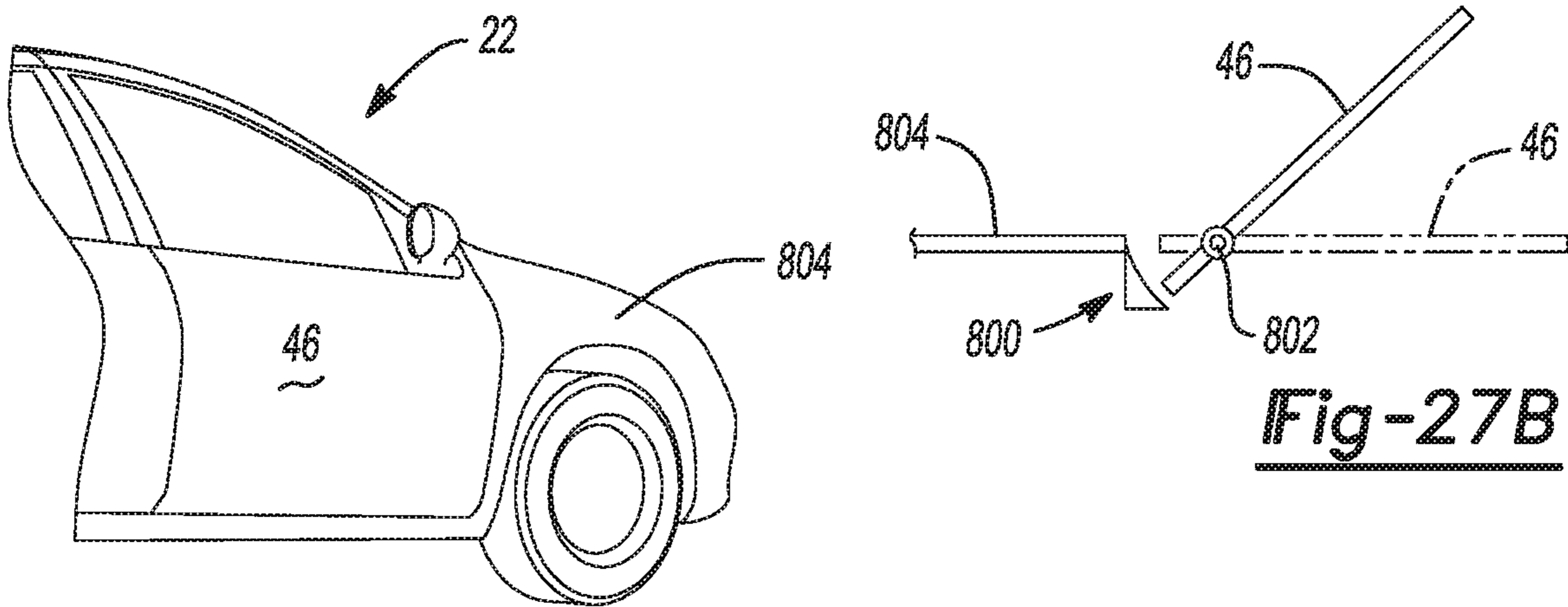


Fig-27A

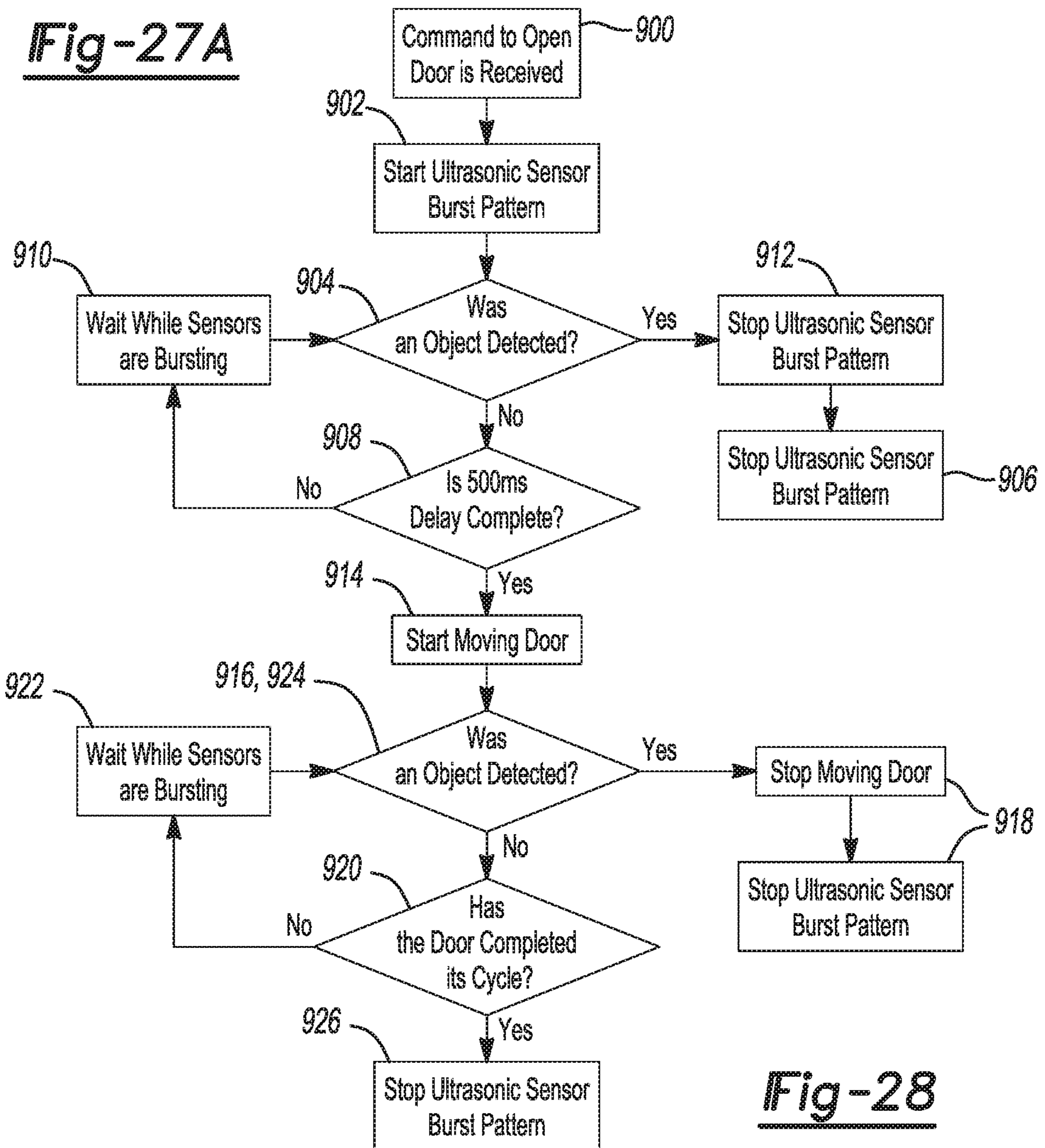


Fig-28



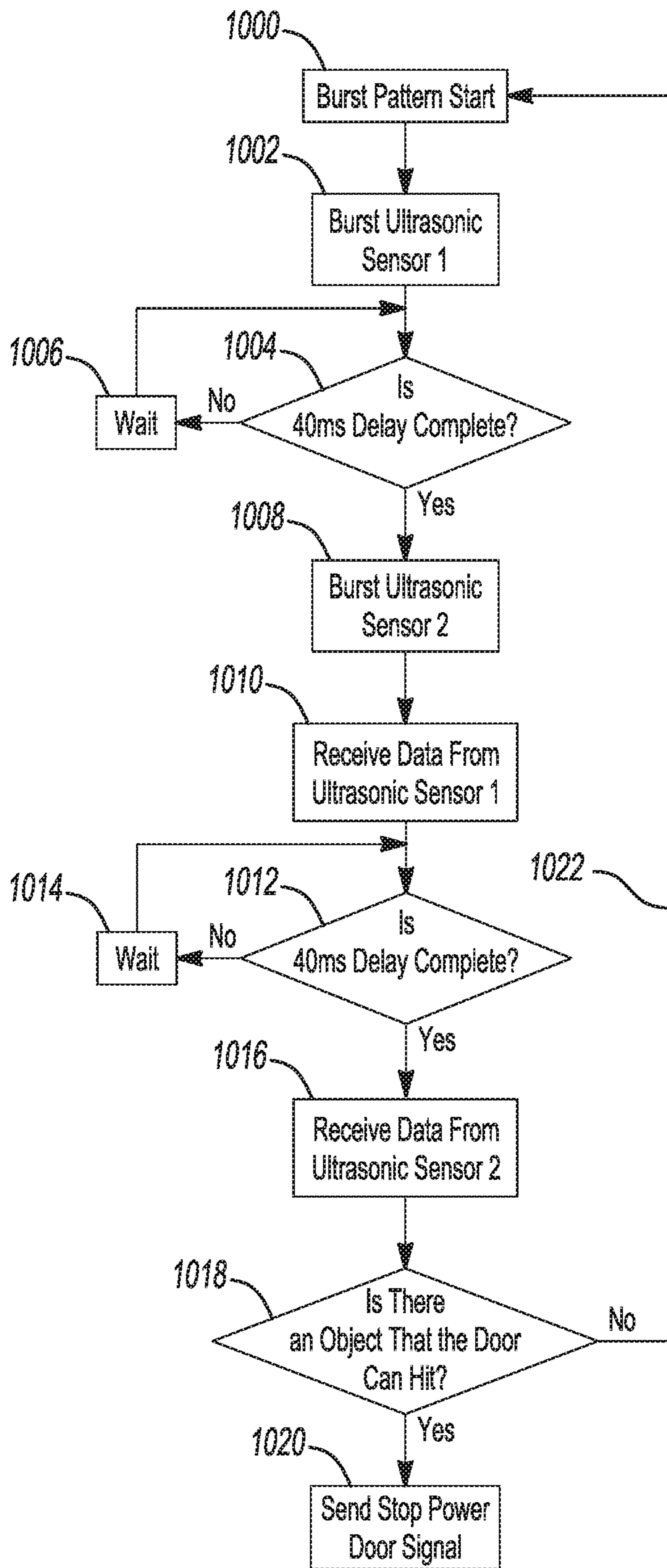


Fig-29

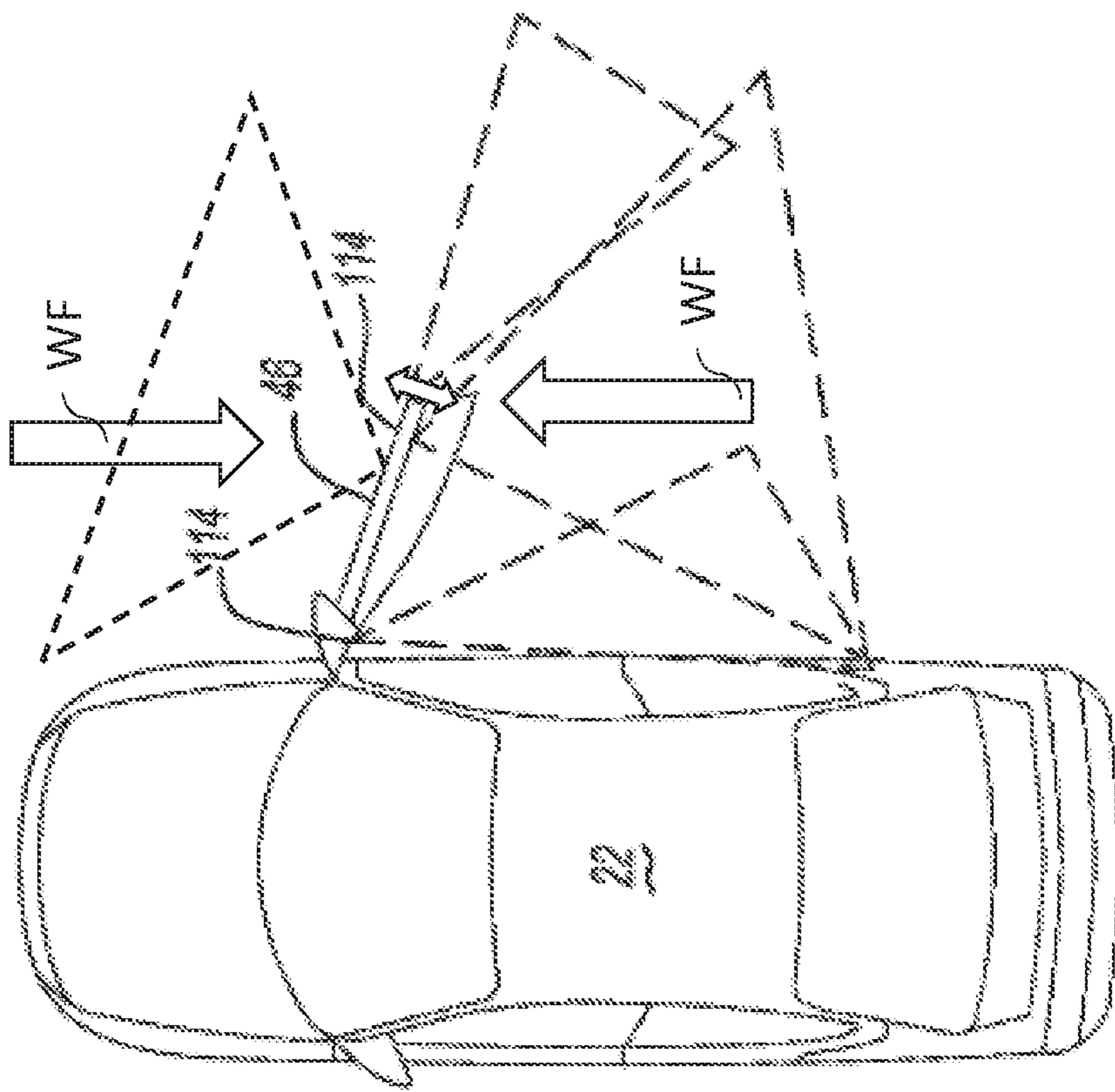


FIG. 30

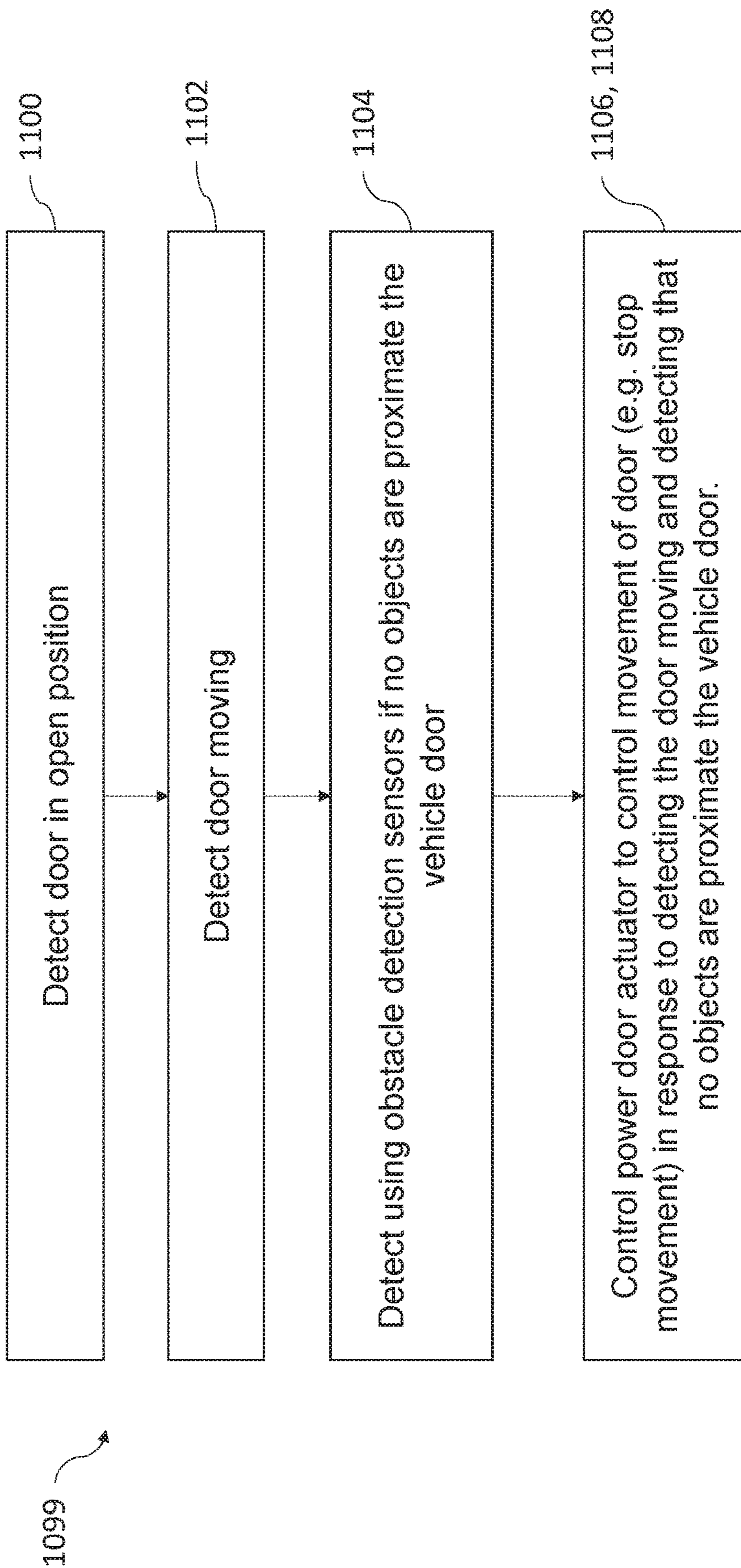


FIG. 31

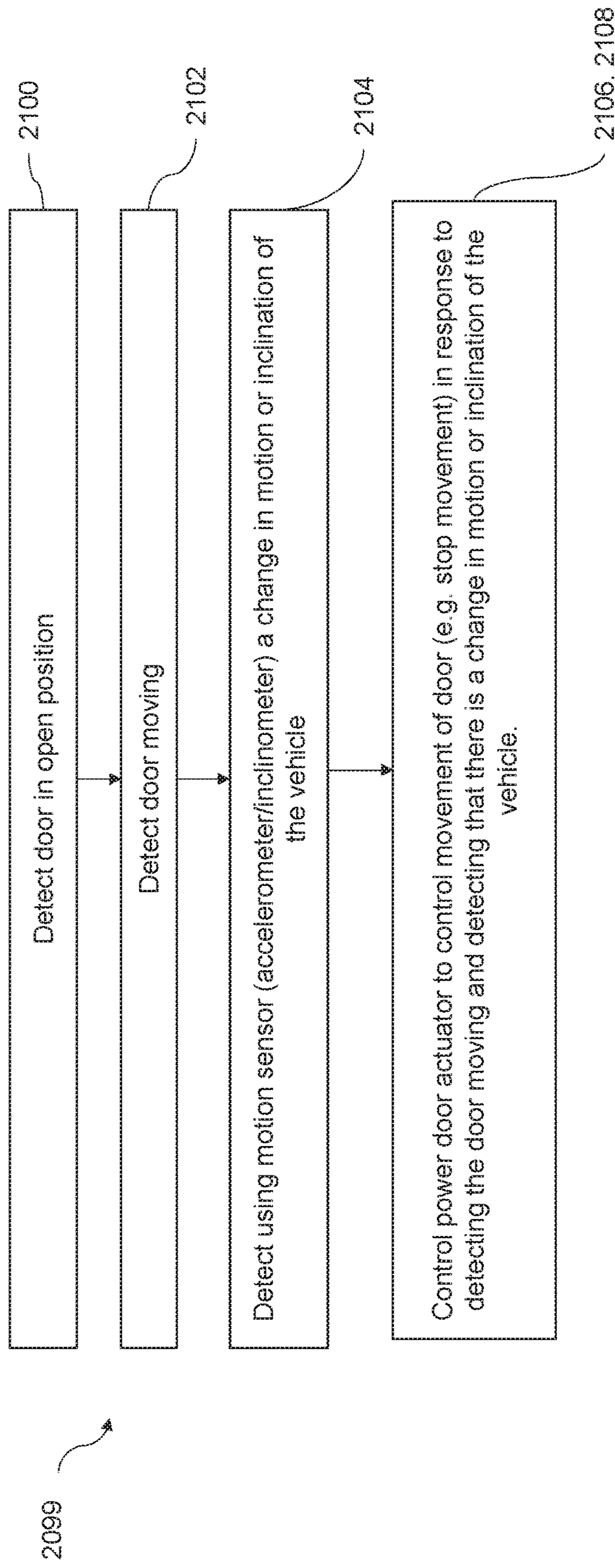


FIG. 32

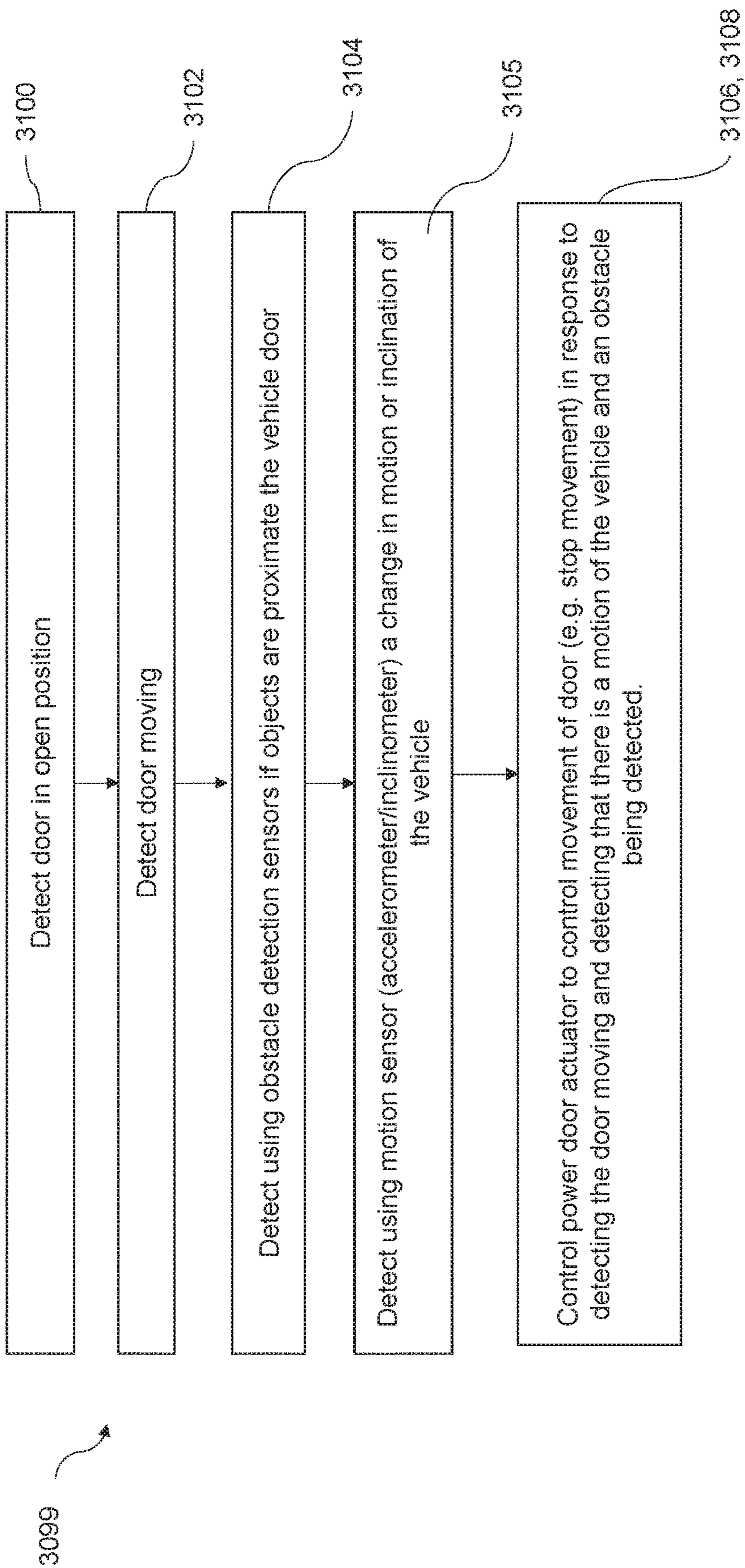


FIG. 33

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**SYSTEM AND METHOD FOR DETECTING  
VEHICULAR DOOR MOVEMENT DUE TO  
NON-CONTACT USING OBSTACLE  
DETECTION**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

This continuation-in-part patent application claims the benefit of U.S. Utility application Ser. No. 15/493,285, filed Apr. 21, 2017, which claims the benefit of U.S. Provisional Application No. 62/327,317 filed Apr. 25, 2016 and U.S. Provisional Application No. 62/460,152 filed Feb. 17, 2017. The entire disclosures of the above applications are incorporated herein by reference.

FIELD

The present disclosure relates generally to a non-contact obstacle detection system for a motor vehicle and method of operating the non-contact obstacle detection system.

BACKGROUND

This section provides background information related to the present disclosure which is not necessarily prior art.

Motor vehicles are increasingly being equipped with sensors that detect the environment and terrain surrounding the motor vehicle. For example, some vehicles include sensor systems that provide images of the terrain and/or other objects in the vicinity of the vehicle. Sensing systems utilizing radar have also been used to detect the presence and position of objects near the motor vehicle while the vehicle is moving. The signals and data generated by these sensor systems can be used by other systems of the motor vehicle to provide safety features such as vehicle control, collision avoidance, and parking assistance. Such sensing systems are generally used to assist the driver while he or she is driving the motor vehicle and/or to intervene in controlling the vehicle.

Additionally, closure members for vehicles (e.g. doors, lift gates, etc.) are increasingly provided with powered actuation mechanisms capable of opening and/or closing the closure members. Typically, powered actuation systems include a power-operated device such as, for example, an electric motor and a rotary-to-linear conversion device that are operable for converting the rotary output of the electric motor into translational movement of an extensible member. In most arrangements, the electric motor and the conversion device are mounted to the closure member and the distal end of the extensible member is fixedly secured to the vehicle body. One example of a such as powered actuation system is shown in commonly-owned U.S. Pat. No. 9,174,517 which discloses a power swing door actuator having a rotary-to-linear conversion device configured to include an externally-threaded leadscrew rotatively driven by the electric motor and an internally-threaded drive nut meshingly engaged with the leadscrew and to which the extensible member is attached. Accordingly, control over the speed and direction of rotation of the leadscrew results in control over the speed and direction of translational movement of the drive nut and the extensible member for controlling swinging movement of the passenger door between its open and closed positions. Such power actuated operation can lead to issues with the closure members unintentionally striking surrounding objects or obstacles. For example, an object near the closure member may obstruct the opening or

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closing of the closure member and/or the closure member may be damaged if opened under power and strikes the obstacle. However, known sensing system or obstacle detection systems do not properly address potential situations involving obstacles.

Powered actuation systems may also need to take into account and/or compensate for effects of wind on the movement of the closure member. For instance, closure members may be inadvertently moved by wind gusts or sustained wind. Wind may also change the rate at which the powered actuator moves the closure member and/or could lead to increased wear or damage to components of the powered actuation system due to increased loading resulting from the wind acting on the closure member. While one solution could involve the use of wind vanes or anemometers to detect wind, such sensor types are generally not well suited to be used on motor vehicles. In addition, such sensors would likely add increased cost and complexity to the powered actuation systems.

Thus, there is an increasing need for an obstacle detection system that prevents the closure member from colliding with nearby objects, while also determining if wind is moving the closure member. Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

SUMMARY

This section provides a general summary of the present disclosure and is not intended to be interpreted as a comprehensive disclosure of its full scope or all of its features, aspects and objectives.

It is an aspect of the present disclosure to provide a non-contact obstacle detection system for a motor vehicle. The non-contact obstacle detection system includes a main electronic control unit having a plurality of input-output terminals and adapted to connect to a power source. At least one non-contact obstacle sensor is coupled to the plurality of input-output terminals of the main electronic control unit for detecting obstacles near a closure member of the vehicle. A power actuator is coupled to the closure member and to the plurality of input-output terminals of the main electronic control unit for moving the closure member. The main electronic control unit is configured to detect movement of the closure member and detect no obstacle using the at least one non-contact obstacle sensor. The main electronic control unit is additionally configured to alter movement of the closure member in response to no obstacle being detected while movement of the closure member is detected.

It is another aspect of the present disclosure to provide a method of operating a non-contact obstacle detection system for a motor vehicle. The method includes the step of determining whether a closure member is in an open position. The next step of the method is determining whether no obstacle is detected using at least one sensor. The method continues with the step of determining whether the closure member is moving in the open position. The method also includes the step of altering motion of the closure member in response to the closure member moving and no obstacle being detected.

These and other aspects and areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are

intended for purpose of illustration only and are not intended to limit the scope of the present disclosure.

## DRAWINGS

The drawings described herein are for illustrative purposes only of selected embodiments and not all implementations, and are not intended to limit the present disclosure to only that actually shown. With this in mind, various features and advantages of example embodiments of the present disclosure will become apparent from the following written description when considered in combination with the appended drawings, in which:

FIGS. 1 and 2 are block diagrams illustrating a non-contact obstacle detection system for a motor vehicle according to aspects of the disclosure;

FIG. 3 illustrates a block diagram of a sensor multiplexer hub of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 4, 5A, 5B, and 6A illustrate a plurality of lift gate TOF (time of flight) proximity sensors of the non-contact obstacle detection system of FIGS. 1 and 2 on a lift gate of a vehicle according to an aspect of the disclosure;

FIG. 6B illustrates a block diagram of a lift gate TOF module of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 7A-7D illustrate sensing capabilities of infrared TOF sensors of the non-contact obstacle detection system of FIGS. 1 and 2 including infrared TOF sensors in an applique of a door according to an aspect of the disclosure;

FIGS. 8A-8D illustrate sensing capabilities of infrared TOF sensors with radar sensing of the non-contact obstacle detection system of FIGS. 1 and 2 including infrared TOF sensors in the applique of the door according to an aspect of the disclosure;

FIGS. 9A-9D illustrate sensing capabilities of ultrasonic sensors with radar sensing of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 10A-10D illustrate sensing capabilities of infrared TOF sensors with radar sensing of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 11A and 11B illustrate a door handle TOF sensor of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 12A-12D illustrate sensing capabilities of infrared TOF sensors with ultrasonic sensing of the non-contact obstacle detection system of FIGS. 1 and 2 including infrared TOF sensors in the applique of the door according to an aspect of the disclosure;

FIGS. 13A-13D illustrate sensing capabilities of ultrasonic sensors with radar and infrared TOF sensing of the non-contact obstacle detection system of FIGS. 1 and 2 including infrared TOF sensors in an applique of a door according to an aspect of the disclosure;

FIGS. 14A-14D illustrate sensing blind spots with a side view mirror TOF sensor of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 15A-15B illustrate a side view mirror TOF sensor of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIGS. 16A-16D illustrate a housing assembly of a TOF sensor of the non-contact obstacle detection system of FIGS. 1 and 2 according to an aspect of the disclosure;

FIG. 17 illustrates steps of a method of teaching a plurality of lift gate TOF modules according to an aspect of the disclosure;

FIG. 18 illustrates steps of a method of operating a lift gate having a plurality of lift gate TOF modules according to an aspect of the disclosure;

FIG. 19 illustrates steps of a method of operating a front door having a side view mirror TOF sensor according to an aspect of the disclosure;

FIG. 20 illustrates steps of a method of operating a rear door using a side view TOF sensor according to an aspect of the disclosure;

FIG. 21 illustrates steps of a method of operating a side door having a door handle TOF sensor according to an aspect of the disclosure;

FIG. 22 is a perspective view of an example motor vehicle equipped with a power door actuation system situated between a front passenger swing door and the vehicle body and which is constructed in accordance with the teachings of the present disclosure;

FIG. 23 is a diagrammatic view of the front passenger door shown in FIG. 25, with various components removed for clarity purposes only, in relation to a portion of the vehicle body and which is equipped with the power door actuation system of the present disclosure;

FIGS. 24A and 24B illustrate a pair of ultrasonic transducers of the non-contact obstacle detection system of FIGS. 1 and 2 on a mirror of a vehicle according to an aspect of the disclosure;

FIGS. 25A and 25B illustrate a plurality of ultrasonic transducers of the non-contact obstacle detection system of FIGS. 1 and 2 on a swing door of a vehicle according to an aspect of the disclosure;

FIGS. 26A and 26B illustrate a plurality of ultrasonic transducers of the non-contact obstacle detection system of FIGS. 1 and 2 on a rocker panel of a vehicle according to an aspect of the disclosure;

FIGS. 27A and 27B illustrate a mechanical blocker on a front fender of a vehicle according to an aspect of the disclosure;

FIG. 28 illustrates steps of a method of detecting an object using a pair of ultrasonic transducers according to aspects of the disclosure;

FIG. 29 illustrates steps of a method of operating a pair of ultrasonic transducers in an ultrasonic transducer burst mode according to aspects of the disclosure;

FIG. 30 illustrates operation of the non-contact obstacle detection system of FIGS. 1 and 2 while a wind force acts on the swing door of the vehicle according to aspects of the disclosure;

FIG. 31 illustrates steps of a method of operating the non-contact obstacle detection system to detect no obstacles while movement of the closure member is detected according to aspects of the disclosure;

FIG. 32 illustrates steps of a method of operating the non-contact obstacle detection system to detect a movement of the vehicle while movement of the closure member is detected according to aspects of the disclosure; and

FIG. 33 illustrates steps of a method of operating the non-contact obstacle detection system to detect no obstacles and movement of the vehicle while movement of the closure member is detected according to aspects of the disclosure.

## DETAILED DESCRIPTION

In the following description, details are set forth to provide an understanding of the present disclosure. In some

instances, certain circuits, structures and techniques have not been described or shown in detail in order not to obscure the disclosure.

In general, the present disclosure relates to an obstacle detection system of the type well-suited for use in many applications. More specifically, a non-contact obstacle detection (NCOD) system for a motor vehicle closure system and methods of operating the non-contact obstacle detection system are disclosed herein. The non-contact obstacle detection system of this disclosure will be described in conjunction with one or more example embodiments. However, the specific example embodiments disclosed are merely provided to describe the inventive concepts, features, advantages and objectives will sufficient clarity to permit those skilled in this art to understand and practice the disclosure.

Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a non-contact obstacle detection system **20** for a motor vehicle **22** is disclosed. As best shown in FIGS. **1** and **2**, the non-contact obstacle detection system **20** includes a main electronic control unit **24** that has a plurality of input-output terminals and is adapted to connect to a power source **26** and to a vehicle CAN bus **28** (controller area network). Main electronic control unit **24** may include an inclinometer sensor **25** for measuring an incline of the vehicle **22**, or the vehicle door, such as swing door **46**. Inclinometer sensor **25** may be provided for at other locations within the door, or vehicle, for example as part of Body Control module **27**.

A sensor multiplexer hub **30** is coupled to at least one of the plurality of input-output terminals of the main electronic control unit **24** for providing power to the sensor multiplexer hub **30** and for communication with the main electronic control unit **24** via CAN communication. As best shown in FIG. **3**, the sensor multiplexer hub **30** includes a hub serial bus interface **32** and a hub CAN bus interface **34**. The sensor multiplexer hub **30** additionally includes a hub I<sup>2</sup>C repeater **36** coupled to the hub serial bus interface **32** to provide for communications on an I<sup>2</sup>C bus and a multiplexer **38** coupled to the hub I<sup>2</sup>C repeater **36**. The hub I<sup>2</sup>C repeater **36** can also act as a level translator. In detail, Inter-Integrated Circuit (I<sup>2</sup>C) buses are generally a multi-master, multi-slave, single-ended, serial computer bus. The sensor multiplexer hub **30** additionally includes a hub microcontroller **40** coupled to the multiplexer **38** and to the hub CAN bus interface **34** and a hub voltage regulator **42** for regulating voltage supplied to the sensor multiplexer hub **30**.

Referring back to FIG. **2**, a motor **44** and/or a motor controller is also coupled to one of the plurality of input-output terminals of the main electronic control unit **24** (e.g., for moving a vehicle **22** closure member such as a swing door **46** or a lift gate **48**, shown in FIG. **4**) and may be operated with pulse width modulation by the main electronic control unit **24**. Although only one motor **44** is described and shown in the Figures, it should be appreciated that any number of motors **44** may be utilized.

An LCD unit **50** is also coupled to one of the plurality of input-output terminals of the main electronic control unit **24** for displaying information related to the non-contact obstacle detection system **20** to a user (e.g., obstacle warning messages). A wireless interface unit **52** is also coupled to one of the plurality of input-output terminals of the main electronic control unit **24** for wireless communication. At least one angle sensor **54** (FIG. **1**) may also be coupled to the sensor multiplexer hub **30**. The angle sensor **54** could detect things such as, but not limited to the angle of a swing door **46** of the vehicle **22**.

A lift gate sensor assembly **56** includes a plurality of left lift gate TOF modules **58** and a plurality of right lift gate TOF modules **60** for attachment to a lift gate **48** of a vehicle **22** (FIGS. **4**, **5A**, **5B**, and **6A**) and for detecting obstacles (and gestures) near the lift gate **48** and for outputting lift gate TOF sensor signals. The quantity of lift gate TOF modules **58**, **60** depends on the size and shape of the lift gate **48**. Time of flight (TOF) sensing allows an absolute distance to be measured independently of a target's reflectance. Sensors utilizing this technology measure the amount of time it takes light to travel from an emitter to the target and back (i.e., time of flight). As described herein, the TOF sensors utilize infrared (IR) light.

As best shown in FIG. **6B**, the left and right lift gate TOF modules **58**, **60** each include a lift gate TOF module CAN bus interface **70** and a plurality of lift gate TOF proximity sensors **62**. The lift gate TOF proximity sensors **62** can, for example, have a range of approximately 40 centimeters and can also include an integrated transmitter/receiver in one microchip. The left and right lift gate TOF modules **58**, **60** each also include a lift gate TOF module I<sup>2</sup>C repeater **72** coupled to the lift gate TOF proximity sensors **62** and to the lift gate TOF module CAN bus interface **70**.

Referring back to FIG. **2**, the lift gate sensor assembly **56** includes a left I<sup>2</sup>C module **74** coupled to the left lift gate TOF modules **58** for communicating the lift gate TOF sensor signals from the left lift gate TOF modules **58** to the sensor multiplexer hub **30**. Similarly, the lift gate sensor assembly **56** additionally includes a right I<sup>2</sup>C module **76** coupled to the right lift gate TOF modules **60** for communicating the lift gate **48** TOF sensor signals from the right lift gate TOF modules **60** to the sensor multiplexer hub **30**. The left I<sup>2</sup>C module **74** and the right I<sup>2</sup>C module **76** of the lift gate sensor assembly **56** are coupled to the sensor multiplexer hub **30** for providing power to the lift gate sensor assembly and for communication between the main electronic control unit **24** and the lift gate sensor assembly **56**. It should be appreciated that the plurality of lift gate TOF proximity sensors **62** could instead comprise sensors utilizing ultrasonic transducers or radar.

A graphics voltage converter **78** is coupled to the sensor multiplexer hub **30** for converting an input voltage from the sensor multiplexer hub **30** to a graphics output voltage. A GPU **80** (graphics processing unit) is coupled to the graphics voltage converter **78** and configured to operate using the graphics output voltage from the graphics voltage converter **78** for processing graphics data. A camera **82** is coupled to the GPU **80** for attachment to the vehicle **22** and for capturing computer vision imaging. An illumination unit **84** is coupled to the camera **82** for providing illumination for the computer vision imaging by the camera **82**. The camera **82** may include complementary metal oxide semi-conductor (CMOS) charge-coupled device (CCD) type image sensors, for example. The camera **82** can generate imaging of a target area and can, for example, be used for determining speed or direction of an object (e.g., an obstacle), the shape and/or contour of the object, and/or otherwise assist the non-contact obstacle detection.

A front and rear side door sensor assembly **86** includes a plurality of door handle TOF sensors **64** each for attachment to one of a front and rear side door handle **88** (FIGS. **7A-7D**, **8A-8D**, **9A-9D**, and **10A-10D**) and for detecting obstacles near the front and rear side door handles **88**. Each of the plurality of door handle TOF sensors **64** can have a 1 meter range, for example, and may also include an integrated transmitter/receiver in a single microchip. The plurality of door handle TOF sensors **64** are coupled to one another and



to at least one of the plurality of input-output terminals of the main electronic control unit **24**. As shown in FIGS. 7A-7D, the non-contact obstacle detection system **20** for the motor vehicle **22** may utilize IR TOF sensing alone (including in an applique **89** of the door **46**). In contrast, in FIGS. 8A-8D, TOF sensors may be used in the handle **88** (e.g., door handle TOF sensors **64**) and the applique **89** of the door **46** for detecting obstacles and gestures, while radar may be used in the rocker panel for detecting obstacles. In FIGS. 9A-9D, ultrasonic sensors or transducers **114** may be disposed in the handle **88** and/or belt line, while radar is utilized in the rocker panel (all are used for obstacle detection). In FIGS. 10A-10D, door handle TOF sensors **64** may be used in the handle **88**, and radar may be utilized in the rocker panel.

As best shown in FIGS. 11A and 11B, the plurality of door handle TOF sensors **64** each include a door handle wiring harness connector **90** and a door handle voltage regulator **92** coupled to the door handle wiring harness connector **90** for regulating a door handle input voltage and outputting a door handle output voltage. The plurality of door handle TOF sensors **64** each also include a door handle I<sup>2</sup>C repeater **94** coupled to the door handle voltage regulator **92** and to the door handle wiring harness connector **90** and a door handle TOF sensor IC **96** coupled to the door handle I<sup>2</sup>C repeater **94** and the door handle voltage regulator **92**. It should be appreciated that the plurality of door handle TOF sensors **64** could instead comprise ultrasonic sensors or transducers **114** (FIGS. 12A-12D and 13A-13D) or radar.

The front and rear side door sensor assembly **86** also includes a plurality of side view mirror TOF sensors **66** for attachment to one of a right and a left side view mirror **98** (FIGS. 7A-7D and 14A-14D) and for detecting obstacles near the right and left side view mirrors **98**. The plurality of side view mirror TOF sensors **66**, for example, can have a 2.5 meter range. The plurality of side view mirror TOF sensors **66** are coupled to one another and to at least one of the plurality of input-output terminals of the main electronic control unit **24** (FIG. 2). In the case of ultrasonic sensors disposed on the side view mirrors **98** in FIGS. 12A-12B in combination with ultrasonic sensors **114** in the door handle **88** and/or belt line with IR TOF sensors in the applique **89**, the ultrasonic sensors **114** may be used for sensing obstacles and the IR TOF sensors in the applique **89** can be used to detect gestures. In FIGS. 13A-13D, ultrasonic sensors **114** can be disposed in the door handle **88** and/or belt line and IR TOF sensors can be disposed in the applique **89** with radar sensors in the rocker panel. The ultrasonic sensors **114** and radar may be used for sensing obstacles and the ultrasonic sensors **114** in the applique **89** can be used to detect gestures.

As best shown in FIGS. 15A and 15B, the plurality of side view mirror TOF sensors **66** each include a side view mirror wiring harness connector and driver **100** and a side view mirror transmitter **102** (e.g., IR light emitting diode transmitter, for example, OSRAM SFH 4550) for transmitting a side view TOF beam. The plurality of side view mirror TOF sensors **66** each also include a side view mirror receiver **104** (e.g., photodiode, for example, OSRAM SFH 213 or SFH 213 FA) for receiving a reflected side view TOF beam in response to the transmission of the side view TOF beam by the side view mirror transmitter **102**. The side view mirror receiver **104** converts the return signal into a current signature. A side view mirror I<sup>2</sup>C repeater **106** is coupled to the side view mirror wiring harness connector and driver **100**. A side view mirror TOF sensor IC **108** (integrated circuit, for example, Intersil ISL29501) is coupled to the side view mirror transmitter **102** and the side view mirror receiver **104** and to the side view mirror I<sup>2</sup>C repeater **106**. The side view

mirror TOF sensor IC **108** calculates the time of flight of the target using signal processing (i.e., the time of flight is proportional to the target distance). It should be appreciated that the plurality of side view mirror TOF sensors **66** could instead comprise sensors utilizing ultrasonic transducers **114** (FIGS. 12A-12D) or radar. As illustrated in FIGS. 14A-14D, the plurality of side view mirror TOF sensors **66** can also be used during motion of the vehicle **22** for monitoring blind spots.

A LIN bus interface unit **110** (FIG. 2) is coupled to at least one of the plurality of input-output terminals of the main electronic control unit **24**. The LIN bus interface provides for communication over a Local interconnect network (LIN). Local interconnect network provides for communication between components on the vehicle **22** via a serial network protocol. An ultrasonic sensor driver ECU **112** (electronic control unit) is coupled to the LIN bus interface. A plurality of the ultrasonic transducers **114** are coupled to the ultrasonic sensor driver ECU **112** for attachment to at least one of a front and a rear power swing door **46** (e.g., belt line or rocker panel location of the vehicle **22**, as shown in FIGS. 13A-13D and 14A-14D) and for detecting obstacles near the front and rear power swing doors **46**. It should be appreciated that the plurality of ultrasonic transducers **114** could instead comprise sensors utilizing TOF technology (FIGS. 8A-8D and 9A-9D) or radar (FIGS. 10A-10D).

As best shown in FIGS. 16A and 16B, each of the lift gate TOF modules **58**, **60**, door handle TOF sensors **64**, and side view mirror TOF sensors **66** can include a housing assembly **116** that comprises a housing top **118** and a housing bottom **120**, each made of plastic (e.g., polypropylene and/or acrylonitrile butadiene styrene), for example. The housing top **118** includes an opening containing a window **122** of acrylic (e.g., that is transparent to infrared light). In detail, the window **122** has a low friction coating (such as an omniphobic coating like fluorodecyl POSS), so that dirt/contamination cannot adhere to the window **122**. The window **122** must remain debris free to permit the infrared TOF to function effectively. A heater could also be added to the housing assembly **116** to melt snow or ice off of the window **122**. A sensor printed circuit board **124** (FIG. 16B) that has a sensor IC attached as well as a plurality of wiring harness connectors (e.g., door handle wiring harness connector **90** or side view mirror wiring harness connector **100**) is disposed within the housing assembly **116**. The housing bottom **120** can include one or more apertures to accommodate the wiring harness connectors. While such a specific structure may be utilized, it should be understood that each of the lift gate TOF modules **58**, **60**, door handle TOF sensors **64**, and side view mirror TOF sensors **66** may take other forms.

As illustrated in FIG. 17, a method of teaching a plurality of lift gate TOF modules **58**, **60** is also disclosed and may only be performed once at a vehicle manufacturer so that the non-contact obstacle detection system **20** of the motor vehicle **22** learns the shut face/seal geometry as the lift gate **48** is closing. The non-contact obstacle detection system **20** learns a shut face distance value from each lift gate TOF modules **58**, **60** and will record teach data (i.e., recorded profiles) in non-volatile memory. The method of teaching a plurality of lift gate TOF modules **58**, **60** includes the step of **200** maintaining the main electronic control unit **24** in a stand-by state. Then, **202** periodically scanning for a lift gate TOF teach signal using the main electronic control unit **24** in the stand-by state. The method proceeds by **204** returning to the stand-by state in response to not detecting the lift gate TOF teach signal. Next, **206** commanding a lift gate **48** to move from a full closed position to a full open position in

response to detecting the lift gate TOF teach signal. The method proceeds by, **208** determining whether the lift gate **48** is in the full open position once motion of the lift gate **48** has ceased (e.g., using the angle sensor **54**, Hall-effect sensors, or other sensors to detect the position). The next step of the method is **210** returning to the stand-by state in response to a determination that the lift gate **48** is not in the full open position. Then, **212** commanding the lift gate **48** to move from the full open position to the full closed position in response to determining that the lift gate **48** is in the full open position. The method continues by, **214** recording a plurality of lift gate TOF signals from the lift gate TOF modules **58**, **60** using the main electronic control unit **24** during movement of the lift gate **48** to the full closed position. The method also includes the steps of **216** generating a plurality of recorded profiles based on the plurality of lift gate TOF signals and **218** storing the plurality of recorded profiles in a non-volatile memory. Then, the method includes the step of **220** determining whether the method of teaching the plurality of lift gate TOF modules **58**, **60** has been completed. Then, **222** returning to the step of commanding the lift gate **48** to move from the full closed position to the full open position (i.e., step **206**) in response to a determination that the method of teaching has not been completed. The method concludes by, **224** ending the method of teaching the plurality of lift gate TOF modules **58**, **60** in response to determining that the method of teaching the plurality of lift gate TOF modules **58**, **60** has been completed. During normal cycling of the lift gate **48**, the system will compare the data from this method of teaching (i.e., recorded profiles) to real-time data to determine if there is an object or obstacle present.

As best shown in FIG. **18**, a method of operating a lift gate **48** (i.e., normal operation) having a plurality of lift gate TOF modules **58**, **60** is also disclosed and includes the step of **300** maintaining the main electronic control unit **24** in a stand-by state. Then, **302** periodically scanning for a lift gate fob signal using the main electronic control unit **24** in the stand-by state and **304** returning to the stand-by state in response to not detecting the lift gate fob signal. The method continues by, **306** determining whether the lift gate **48** is in an open position in response to detecting the lift gate fob signal.

The method of operating a lift gate **48** having a plurality of lift gate TOF modules **58**, **60** proceeds by, **308** commanding the lift gate **48** to move from a full closed position to a full open position in response to a determination that the lift gate **48** is not in the open position. Next, **310** commanding the lift gate **48** to move from the open position to the full closed position and **312** activating a scan of a plurality of lift gate TOF signals from a plurality of lift gate TOF modules **58**, **60**. The next step of the method is **314** generating a plurality of lift gate **48** TOF sensor profiles based on the plurality of lift gate TOF signals. Then, **316** comparing the plurality of lift gate TOF sensor profiles to a plurality of stored recorded profiles.

The method of operating a lift gate **48** having a plurality of lift gate TOF modules **58**, **60** then includes the step of **318** determining whether a difference between a distance measured during motion of the lift gate **48** and a stored distance value exceeds a threshold. The method also includes the step of **320** continuing to close the lift gate **48** in response to a determination that the difference between the distance measured during motion of the lift gate **48** and the stored distance value does not exceed the threshold.

The method of operating a lift gate **48** having a plurality of lift gate TOF modules **58**, **60** also includes the step of **322**

determining whether the lift gate **48** is in the open position and **324** returning to the step of generating a plurality of lift gate TOF sensor profiles based on the plurality of lift gate TOF signals in response to a determination that the lift gate **48** is in the open position. The next step of the method is **326** registering that the lift gate **48** is closed and the next lift gate fob signal will cause the lift gate **48** to move in an opening direction in response to a determination that the lift gate **48** is not in the open position. The method concludes by, **328** stopping motion of the lift gate **48** and **330** registering that the next lift gate fob signal will cause the lift gate **48** to move in the opening direction in response to a determination that the difference between the distance measured during motion of the lift gate **48** and the stored distance value exceeds the threshold.

As illustrated in FIG. **19**, a method of operating a front door (e.g., swing door **46**) having a side view mirror TOF sensor **66** is additionally disclosed and includes the step of **400** maintaining the main electronic control unit **24** in a stand-by state. Then, **402** periodically scanning for a front door opening signal using the main electronic control unit **24** in the stand-by state. The next step of the method is **404** returning to the stand-by state in response to not detecting the front door opening signal.

The method of operating a front door having a side view mirror TOF sensor **66** also includes the step of **406** determining whether a rear door is in an open position in response to detecting the front door opening signal. The method proceeds by, **408** detecting an obstacle using short range detection with the plurality of side view mirror TOF sensors **66** in response a determination that the rear door is in the open position. Next, **410** ceasing door opening and disabling system in response to the obstacle being detected. It should be appreciated that while these steps involve the door opening, the method may alternatively include closing the closure member or door.

The method of operating a front door having a side view mirror TOF sensor **66** proceeds by, **412** releasing a latch and applying power to a motor **44** in response to the obstacle not being detected and determining whether the front door is in a full open position. The next step of the method is **414** continuing to apply power to the motor **44** in response to a determination that the front door is not in the full open position. The method also includes the steps of **416** returning to the step of detecting if the obstacle is detected using short range detection and **418** concluding that the front door is open in response to a determination that the front door is in the full open position.

The method of operating a front door having a side view mirror TOF sensor **66** continues with the step of **420** detecting if the obstacle is detected using long range detection with the plurality of side view mirror TOF sensors **66** in response to a determination that the rear door is not in the open position. Then, the method includes the step of **422** ceasing door opening and disabling system in response to the obstacle being detected. The method proceeds by, **424** releasing the latch and applying power to the motor **44** in response to the obstacle not being detected.

The method operating a front door having a side view mirror TOF sensor **66** then includes the step of **426** determining whether the front door is in the full open position. Next, **428** continuing to apply power to the motor **44** in response to a determination that the front door is not in the full open position. The method proceeds by, **430** returning to the step of detecting if the obstacle is detected using long range detection. The method then completes with the step of

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432 concluding that the front door is open in response to a determination that the front door is in the full open position.

As illustrated in FIG. 20, a method of operating a rear door (e.g., swing door 46) using a side view mirror TOF sensor 66 is also disclosed and includes the step of 500 5 maintaining the main electronic control unit 24 in a stand-by state. Then, 502 periodically scanning for a rear door opening signal using the main electronic control unit 24 in the stand-by state and 504 returning to the stand-by state in response to not detecting the front door opening signal.

The method of operating a rear door using a side view mirror TOF sensor 66 continues with the step of 506 determining whether a front door is in an open position in response to detecting the front door opening signal. Then, 508 ignoring the side view mirror TOF sensor 66 of the front door in response to a determination that the front door is in the open position. The next step of the method is 510 detecting an obstacle using long range detection with the side view mirror TOF sensor 66 in response to a determination that the front door is not in the open position. The method continues by 512 ceasing door opening and disabling system in response to the obstacle being detected. It should be understood that while these steps involve the door opening, the method may alternatively include closing the door or closure member.

The method of operating a rear door using a side view mirror TOF sensor 66 also includes the step of 514 releasing the latch and applying power to the motor 44 in response to the obstacle not being detected. Next, 516 determining whether the rear door is in the full open position and 518 continuing to apply power to the motor 44 in response to a determination that the front door is not in the full open position. The method continues by, 520 returning to the step of detecting if the obstacle is detected using long range detection. The final step of the method is 522 concluding that the rear door is open in response to a determination that the rear door is in the full open position.

As illustrated in FIG. 21, a method of operating a side door (e.g., swing door 46) having a door handle TOF sensor 64 and rocker panel sensors is additionally disclosed and includes the step of 600 maintaining the main electronic control unit 24 in a stand-by state. Then, 602 periodically scanning for a side door opening signal using the main electronic control unit 24 in the stand-by state. The method continues by 604 returning to the stand-by state in response to not detecting the side door opening signal.

The method of operating a side door having a door handle TOF sensor 64 also includes the step of 606 activating non-contact obstacle detection in response to detecting the side door opening signal. Next, 608 detecting an obstacle using the door handle TOF sensor 64 in response to a determination that the side door is not in the open position. The method proceeds by 610 ceasing door opening and disabling the system in response to the obstacle being detected.

The method of operating a side door having a door handle TOF sensor 64 also includes the step of 612 releasing the latch and applying power to the motor 44 in response to the obstacle not being detected. Then, 614 determining whether the side door is in the full open position. The method then includes the step of 616 continuing to apply power to the motor 44 in response to a determination that the front door is not in the full open position. Next, 618 returning to the step of detecting if the obstacle is detected using the door handle TOF sensor 64 and 620 concluding that the side door is open in response to a determination that the side door is in the full open position.

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Referring initially to FIG. 22, an example motor vehicle 710 is shown to include a first passenger door 712 pivotably mounted to a vehicle body 714 via an upper door hinge 716 and a lower door hinge 718 which are shown in phantom lines. In accordance with the present disclosure, a power door actuation system 720 is integrated into the pivotal connection between first passenger door 712 and a vehicle body 714. The power door actuation system 720 can be integrated into the non-contact obstacle detection system 20 of the present disclosure. In accordance with a preferred configuration, power door actuation system 720 generally includes a power actuator or power-operated swing door actuator secured within an internal cavity of passenger door 712 and including an electric motor driving a spindle drive mechanism having an extensible component that is pivotably coupled to a portion of the vehicle body 714. Driven rotation of the spindle drive mechanism causes controlled pivotal movement of passenger door 712 relative to vehicle body 714.

Each of upper door hinge 716 and lower door hinge 718 include a door-mounting hinge component and a body-mounted hinge component that are pivotably interconnected by a hinge pin or post. While power door actuation system 720 is only shown in association with front passenger door 712, those skilled in the art will recognize that the power door actuation system can also be associated with any other door or lift gate of vehicle 710 such as rear passenger doors 717 and decklid 719.

Power door actuation system 720 is diagrammatically shown in FIG. 23 to include a power swing door actuator 722 configured to include an electric motor 724, a reduction geartrain 726, a slip clutch 728, and a drive mechanism 730 which together define a power assembly 732 that is mounted within an interior chamber 734 of door 712. Power swing door actuator 722 further includes a connector mechanism 736 configured to connect an extensible member of drive mechanism 730 to vehicle body 714. A brake mechanism 725, such as an electromagnetic brake assembly, may be provided, and illustratively shown coupled to a shaft of the electric motor 724 and controlled by the electronic control module 752 for holding or releasing the rotation of the motor and thus the ultimately braking the movement of the door 712. The brake 725 may act on other components of the power swing door actuator 722, or generally on the door to stop the motion of the door 712, for example a brake 725 may be provided to act on the hinges 716, 718, or on a door check mechanism 727 for example as described in commonly owned US Patent Application No. US20190112849 entitled "Power-operated variable force door check mechanism for a vehicular closure system" the entire contents of which are incorporated by reference, provided between the vehicle body 714 and the vehicle door 712, as examples. As also shown, an electronic control module 752 is in communication with electric motor 724 for providing electric control signals thereto. Electronic control module 752 can include a microprocessor 754 and a memory 756 having executable computer readable instructions stored thereon.

Although not expressly illustrated, electric motor 724 can include Hall-effect sensors for monitoring a position and speed of vehicle door 712 during movement between its open and closed positions. For example, one or more Hall-effect sensors may be provided and positioned to send signals to electronic control module 752 that are indicative of rotational movement of electric motor 724 and indicative of the rotational speed of electric motor 724, e.g., based on counting signals from the Hall-effect sensor detecting a target on a motor output shaft. In situations where the sensed

motor speed is greater than a threshold speed and where the current sensor registers a significant change in the current draw, electronic control module 752 may determine that the user is manually moving door 712 while motor 724 is also operating, thus moving vehicle door 712 between its open and closed positions. Electronic control module 752 may then send a signal to electric motor 724 to stop motor 724 and may even disengage slip clutch 728 (if provided). Conversely, when electronic control module 752 is in a power open or power close mode and the Hall-effect sensors indicate that a speed of electric motor 724 is less than a threshold speed (e.g., zero) and a current spike is registered, electronic control module 752 may determine that an obstacle is in the way of vehicle door 712, in which case the electronic control system may take any suitable action, such as sending a signal to turn off electric motor 736. As such, electronic control module 752 receives feedback from the Hall-effect sensors to ensure that a contact obstacle has not occurred during movement of vehicle door 712 from the closed position to the open position, or vice versa.

As is also schematically shown in FIG. 23, electronic control module 752 can be in communication with a remote key fob 760 or an internal/external handle switch 762 for receiving a request from a user to open or close vehicle door 712. Put another way, electronic control module 752 receives a command signal from either remote key fob 760 and/or internal/external handle switch 762 to initiate an opening or closing of vehicle door 712. Upon receiving a command, electronic control module 752 proceeds to provide a signal to electric motor 724 in the form of a pulse width modulated voltage (for speed control) to turn on motor 724 and initiate pivotal swinging movement of vehicle door 712. While providing the signal, electronic control module 752 also obtains feedback from the Hall-effect sensors of electric motor 724 to ensure that a contact obstacle has not occurred. If no obstacle is present, motor 736 will continue to generate a rotational force to actuate spindle drive mechanism 730. Once vehicle door 712 is positioned at the desired location, motor 724 is turned off and the “self-locking” gearing associated with gearbox 726 causes vehicle door 712 to continue to be held at that location. If a user tries to move vehicle door 712 to a different operating position, electric motor 724 will first resist the user’s motion (thereby replicating a door check function) and eventually release and allow the door to move to the newly desired location. Again, once vehicle door 712 is stopped, electronic control module 752 will provide the required power to electric motor 724 to hold it in that position. If the user provides a sufficiently large motion input to vehicle door 712 (i.e., as is the case when the user wants to close the door), electronic control module 752 will recognize this motion via the Hall effect pulses and proceed to execute a full closing operation for vehicle door 712.

Electronic control module 752 can also receive an additional input from a sensor, as previously disclosed herein, positioned on a portion of vehicle door 712, such as on a door mirror 765, or the like. Sensor 764 assesses if an obstacle, such as another car, tree, or post, is near or in close proximity to vehicle door 712. If such an obstacle is present, sensor 764 will send a signal to electronic control module 752, and electronic control module 752 will proceed to turn off electric motor 724 to stop movement of vehicle door 712, and thus prevent vehicle door 712 from hitting the obstacle. This provides a non-contact obstacle avoidance system. In addition, or optionally, a contact obstacle avoidance system can be placed in vehicle 710 which includes a contact sensor

766 mounted to door, such as in association with molding component 767, and operable to send a signal to controller 752.

A power actuator disclosed in commonly-owned U.S. Pat. No. 9,174,517, incorporated by reference herein, is one non-limiting example of a power closure arrangement configured to be easily integrated into the non-contact obstacle detection system of the present disclosure. Specifically, this is an example of a non-contact obstacle detection system that can be used in association with the motor of the power actuator to drive the closure member, and an absolute position sensor can be used to determine the full open position. Other powered devices, such as power release latches can be used with this non-contact obstacle detection system. For example, non-limiting examples of such power release latches are disclosed in US Publication No. 2015/0330116 and US Publication No. 2012/0313384, each of which is incorporated by reference herein. Similarly, a power lift gate actuator capable of association herewith is disclosed in WO 2014/199235 as is likewise incorporated herein. Finally, a powered strut device for use in power lift gate systems is disclosed in US Publication No. 2015/0376929 and its teachings are further incorporated herein by reference.

According to aspects of the disclosure, the plurality of ultrasonic transducers 114 or sensors coupled to the ultrasonic sensor driver ECU 112 described above can, for example, comprise ultrasonic transducers 114 manufactured by Murata, part number MA-58MF14-7N. Such ultrasonic transducers 114 can exhibit directivity (i.e., the degree to which the radiation emitted from the ultrasonic transducer 114 is concentrated in a single direction). The ultrasonic sensor driver ECU 112 utilized herein, may for example comprise elmos E524.08 or E524.09 ultrasonic sensor drivers. Various software strategies can be employed including auto threshold generation, which is used to eliminate ground reflections. Other software strategies can include, but are not limited to, sensitivity time control (uses fixed versus increasing gain over time), near field threshold generation (used to reduce/eliminate ringing characteristics that occur during transmission bursts), and controllable listening window length (varies the transmit and receive time). However, it should be appreciated that various other types of ultrasonic transducers 114, ultrasonic transducer driver ECUs 112, and/or software strategies may be utilized.

FIGS. 24A and 24B illustrate a specific packaging location and sensing zones of the ultrasonic transducers 114 on the underside of an outside mirror of the vehicle 22. Specifically, a pair of ultrasonic transducers 114 can be mounted with sensing zones shown in FIGS. 24A and 24B. The ultrasonic sensing zones are projected backward to provide NCOD coverage to a rear door (i.e., for a four door vehicle) as well. The ultrasonic sensing zones protect the front door during the power open cycle.

According to aspects of the disclosure, the plurality of ultrasonic transducers 114 can, for example, include a first ultrasonic transducer 114 (e.g., with an eighty degree sense zone) and a second ultrasonic transducer 114 (e.g., with a thirty four degree sense zone) disposed along a lower inner edge of the swing door 46 (FIGS. 25A and 25B). In more detail, the first ultrasonic transducer 114 is used to detect objects in the path of the closing door (i.e., the first ultrasonic transducer 114 can be off while the swing door 46 is opening). The second ultrasonic transducer 114 can also be used to detect objects in the path of closing swing door 46 (e.g., front door of the vehicle 22), such as a knee, and the second ultrasonic transducer 114 can also be off or disabled

while the swing door **46** is opening. A third ultrasonic transducer **114** can also be implemented for non-contact obstacle detection of the rear door while opening.

FIGS. **26A** and **26B** illustrate the plurality of ultrasonic transducers **114** disposed in a rocker panel of the vehicle **22** (e.g., under the front door). Such ultrasonic transducers **114** disposed on or inside a rocker panel can be used to detect objects (e.g., the curb) in the path of the front door (e.g., swing door **46**) while it is opening or while the front door is closing (e.g., a leg).

According to other aspects of the present disclosure, a mechanical block **800** (FIGS. **27A** and **27B**) can be disposed at the front door (swing door **46**), near hinges **802** of the door **46** to prevent a pinch condition (e.g., pinched fingers). The mechanical block **800** can, for example, be coupled to an inside edge of a front door fender **804**. As the door **46** opens, the front edge of the door **46** swings inwardly and creates a cavity between the front edge and an edge of the front door fender **804**. By placing the mechanical block **800** on the front door fender **804**, the cavity is never formed, since the mechanical block **800** would keep the same distal relationship to the front edge of the door **46** as it swings inwardly.

As illustrated in FIG. **28**, a method of detecting an object using a pair of ultrasonic transducers **114** is disclosed. While a pair of ultrasonic transducers **114** is employed, it should be appreciated that any number of ultrasonic transducers **114** may alternatively be used. The method includes the step of **900** receiving a command to open a swing door **46**. Next, **902** starting an ultrasonic transducer burst pattern (e.g., instantaneous or short instance of emission from the ultrasonic transducers **114** using the pair of ultrasonic transducers **114**). The method proceeds by **904** determining whether an object is detected by the pair of ultrasonic transducers **114** during the ultrasonic burst pattern. The method continues by **906** stopping the ultrasonic transducer burst pattern in response to the object being detected.

The method can also include the step of **908** determining whether a first predetermined amount of time (e.g., 500 milliseconds) has elapsed in response to the object not being detected. The method proceeds with the step of **910** waiting while the pair of ultrasonic transducers **114** is bursting during the ultrasonic transducer burst pattern after determining whether the first predetermined amount of time has elapsed. Next, **912** continuing to determine whether an object is detected by the pair of ultrasonic transducers **114** in response to the object not being detected and after waiting while the pair of ultrasonic transducers **114** is bursting during the ultrasonic transducer burst pattern.

The method can then continue by **914** starting to move the swing door **46** in response to the determination that the first predetermined amount of time has elapsed and the object has not been detected. The method also includes the step of **916** determining whether an object is detected by the pair of ultrasonic transducers **114** while the swing door is moving. Next, **918** stopping the swing door and the ultrasonic transducer burst pattern in response to the object being detected. The next step of the method is **920** determining whether the swing door **46** has completed its cycle (e.g., completely opened) in response to the object not being detected. Next, **922** waiting while the pair of ultrasonic transducers **114** is bursting during the ultrasonic transducer burst pattern in response to a determination that the swing door **46** has not completed its cycle. The method proceeds by **924** continuing to determine whether an object is detected by the pair of ultrasonic transducers **114** in response to the object not being detected and after waiting while the pair of ultrasonic transducers **114** is bursting. The method also includes the

step of **926** stopping the ultrasonic transducer burst pattern in response to the door **46** completing its cycle and the object not being detected.

As illustrated in FIG. **29**, a method of operating a pair of ultrasonic transducers **114** in an ultrasonic transducer burst mode is also disclosed. The method includes the step of **1000** initiating an ultrasonic transducer burst pattern using the pair of ultrasonic transducers **114** including a first ultrasonic transducer **114** and a second ultrasonic transducer **114**. The method proceeds by **1002** bursting the first ultrasonic transducer **114** and **1004** determining whether a second predetermined amount of time (e.g., 40 milliseconds) has elapsed after bursting the first ultrasonic transducer **114**. The method also includes the step of **1006** waiting in response to a determination that the second predetermined period of time has not elapsed after bursting the first ultrasonic transducer **114**.

The method then continues by **1008** bursting the second ultrasonic transducer **114** in response to a determination that the second predetermined period of time has elapsed after bursting the first ultrasonic transducer **114**. The method continues by **1010** receiving a first set of data from the first ultrasonic transducer **114** after bursting the second ultrasonic transducer **114**.

The method proceeds with the step of **1012** determining whether a second predetermined amount of time (e.g., 40 milliseconds) has elapsed after bursting the second ultrasonic transducer **114**. Next, **1014** waiting in response to a determination that the second predetermined period of time has not elapsed after bursting the second ultrasonic transducer **114**. The method then includes the step of **1016** receiving a second set of data from the second ultrasonic transducer **114** after waiting in response to a determination that the second predetermined period of time has not elapsed after bursting the second ultrasonic transducer **114**. The next step of the method is **1018** determining whether there is an object that the swing door **46** can hit using the first set of data and the second set of data. The method then includes the step of **1020** sending a stop power door signal (e.g., to power door actuation system **720**) in response to a determination of an object that the swing door **46** can hit. The method also includes the step of **1022** transitioning back to the step of **1000** initiating the ultrasonic transducer burst pattern using the pair of ultrasonic transducers **114** including the first ultrasonic transducer **114** and the second ultrasonic transducer **114** in response to a determination of there not being an object that the swing door **46** can hit.

As best shown in FIG. **30**, the closure the closure member (e.g., swing door **46**) is acted upon by a wind force WF, for example, during movement of the closure member by the power door actuation system **722** while the non-contact obstacle detection system **20** is operating to detect obstacles. This wind force WF may cause unintended or undesirable movement of the closure member (e.g., swing door **46** or first passenger door **712**). Wind gusts or sustained wind may, for example, change the speed at which the powered actuation system (e.g., power door actuation system **720** of FIGS. **22** and **23**) moves the closure member and/or could otherwise affect the powered operation of the powered actuation system. Wind acting on the closure member can also adversely result in increased wear or damage to components of the power actuation system (e.g., reduction geartrain **726**, electric motor **724**) due to increased loading resulting from the wind acting on the closure member. While shown acting on only one side of the closure member, the wind force WF could alternatively act on the opposite side of the closure member instead.

As discussed, the non-contact obstacle detection system **20** can utilize the at least one angle sensor **54** (FIG. **1**) to detect a position and movement of the closure member. Consequently, the main electronic control unit **24** (or electronic control module **752**) is configured to detect movement of the closure member. Because the non-contact obstacle detection system **20** can also detect obstacles or persons near the closure member (e.g., using the plurality of ultrasonic transducers **114**), the main electronic control unit **24**, for instance, can determine that any detected movement of the closure member is likely due to wind force WF. Thus, after the non-contact obstacle detection system **20** detects no contact by a person causing movement of the closure member, the motion of the closure member by the powered actuation system (e.g., power door actuation system **720**) can be stopped or otherwise altered as a result. So, if the main electronic control unit **24** detects that no obstacle is present using the at least one non-contact obstacle sensor (e.g., the plurality of ultrasonic transducers **114**), the main electronic control unit **24** alters movement (e.g., ceases movement) of the closure member in response to no obstacle being detected while movement of the closure member is detected. Therefore, instead of the non-contact obstacle detection system **20** always being operated to sense obstacles to stop the door or closure member when the obstacle is present, the non-contact obstacle detection system **20** can additionally detect movement of a closure member not caused by a person physically moving it, for example, as caused by wind, and without using additional and specialized wind sensors such as wind vanes or anemometers.

As best shown in FIG. **31**, a method of operating the non-contact obstacle detection system **20** to detect movement of the closure member due to non-physical contact with the closure member **1099** (e.g., swing door **46**) is additionally provided. The method begins with the step of **1100** determining whether a closure member is in an open position. The next step of the method is **1102** determining whether the closure member is moving (e.g., while in the open position). The method continues with the step of **1104** determining whether no obstacle is detected using at least one sensor (e.g., the plurality of ultrasonic transducers **114**, or radar sensors). The method proceeds with the step of **1106** altering motion of the closure member in response to the closure member moving and no obstacle being detected. Specifically, the step of altering motion of the closure member in response to the closure member moving and no obstacle being detected may further be defined as **1108** ceasing motion of the closure member in response to the closure member moving and no obstacle being detected.

As best shown in FIG. **32**, a method of operating the non-contact obstacle detection system **20** to detect movement of the closure member due to non-physical contact with the closure member **2099** (e.g., swing door **46**) is additionally provided. The method begins with the step of **2100** determining whether a closure member is in an open position. The next step of the method is **2102** determining whether the closure member is moving (e.g., while in the open position). The method continues with the step of **2104** determining using a motion sensor (for example such as an accelerometer/inclinometer) a change in motion or inclination of the vehicle which may cause the closure member to move unintentionally, for example as a result of a person entering the vehicle on an opposite side of the vehicle causing the closure member to move as a result, or otherwise. The method proceeds with the step of **2106** altering motion of the closure member in response to the closure

member moving and detecting/determining that there is a motion of the vehicle. Specifically, the step of altering motion of the closure member in response to the closure member moving and detecting/determining that there is a motion of the vehicle may further be defined as **2108** ceasing motion of the closure member in response to the closure member moving and detecting/determining that there is a motion of the vehicle.

As best shown in FIG. **33**, a method of operating the non-contact obstacle detection system **20** to detect movement of the closure member due to non-physical contact with the closure member **3099** (e.g., swing door **46**) is additionally provided combining the steps of FIGS. **31** and **32** described hereinabove. The method begins with the step of **3100** determining whether a closure member is in an open position. The next step of the method is **3102** determining whether the closure member is moving (e.g., while in the open position). The method continues with the step of **3104** determining whether an obstacle is detected using at least one sensor, for example a person may be standing next to the closure panel without the intent of moving the closure panel or any interaction with the closure panel. The method continues with the step of **3105** determining using a motion sensor (for example such as an accelerometer/inclinometer) a change in motion or inclination of the vehicle which may cause the closure member to move unintentionally, for example as a result of a person entering the vehicle on an opposite side of the vehicle causing the closure member to move as a result, or as a result of a shift in an unstable ground as examples. The method proceeds with the step of **3106** altering motion of the closure member in response to the closure member moving and detecting/determining that there is a motion of the vehicle and an obstacle being detected. Specifically, the step of altering motion of the closure member in response to the closure member moving and detecting/determining that there is a motion of the vehicle and an obstacle being detected may further be defined as **3108** ceasing motion of the closure member in response to the closure member moving and detecting/determining that there is a motion of the vehicle.

While the detection of wind is discussed in conjunction with swing door **46** of motor vehicle **22**, it should be understood that the non-contact obstacle detection system **20** may instead detect wind and operate other closure members, such as, but not limited to lift gate **48** accordingly. In addition, while the detection of wind is discussed and shown using the plurality of ultrasonic transducers **114**, it should be appreciated that the use other types of non-contact obstacle detection sensors, such as radar or TOF sensors **58**, **60**, **64**, **66** (e.g., infrared) is contemplated.

Clearly, changes may be made to what is described and illustrated herein without, however, departing from the scope defined in the accompanying claims. The non-contact obstacle detection system may operate with myriad combinations of various types of non-contact sensors and for any closure members of the motor vehicle, for example. In general, the non-contact obstacle detection system **20** may be used also for other purposes, within the motor vehicle, or for different automotive applications.

The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such

variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure. Those skilled in the art will recognize that concepts disclosed in association with the non-contact obstacle detection system **20** can likewise be implemented into many other systems to control one or more operations and/or functions.

Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

When an element or layer is referred to as being “on,” “engaged to,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or

feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptions used herein interpreted accordingly.

What is claimed is:

**1.** A non-contact obstacle detection system for a motor vehicle comprising:

a controller adapted to connect to a power source;  
at least one non-contact obstacle sensor coupled to said controller for detecting a person near a closure member of the motor vehicle; and

at least one of:

a power actuator coupled to the closure member and to said controller for moving the closure member and a brake mechanism coupled to said controller;

wherein said controller is configured to:

detect a non-powered movement of the closure member caused by a wind force acting on the closure member,

in response to detecting the non-powered movement of the closure member, operate said at least one non-contact obstacle sensor while movement of the closure member is detected,

determine that no person is detected while said at least one non-contact obstacle sensor is operated during the non-powered movement of the closure member, and

alter movement of the closure member using said at least one of said power actuator and said brake mechanism in response to no person being detected while the non-powered movement of the closure member is detected.

**2.** The non-contact obstacle detection system of claim **1**, wherein said main electronic control unit is further configured to cease movement of the closure member in response to no obstacle being detected while the non-powered movement of the closure member is detected.

**3.** The non-contact obstacle detection system of claim **1**, further including an angle sensor in communication with said main electronic control unit, and wherein said main electronic control unit is further configured to determine whether the closure member is moving using said angle sensor.

**4.** The non-contact obstacle detection system of claim **1**, wherein said at least one non-contact obstacle sensor includes at least one radar sensor.

**5.** The non-contact obstacle detection system of claim **1**, wherein the closure member is a lift gate and said at least one non-contact obstacle sensor includes at least one lift gate proximity sensor for detecting obstacles and gestures near the lift gate.

**6.** The non-contact obstacle detection system of claim **1**, wherein the closure member is a swing door and said at least one non-contact obstacle sensor includes at least one proximity sensor for attachment to the swing door for detecting obstacles near the swing door.

**7.** The non-contact obstacle detection system of claim **1**, wherein said at least one non-contact obstacle sensor includes at least one side mirror proximity sensor for attach-

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ment to a side view mirror of the vehicle for detecting obstacles near the side view mirror.

8. The non-contact obstacle detection system of claim 1, wherein the closure member is a swing door and said power actuator is secured within an internal cavity of the swing door and includes an electric motor driving a spindle drive mechanism having an extensible component that is pivotably coupled to a portion of a body of the vehicle.

9. A method of operating a non-contact obstacle detection system for a motor vehicle comprising the steps of:

determining whether a closure member is in an open position;

determining whether a power actuator coupled to the closure member is off;

determining whether the closure member is being manually moved when the power actuator is off;

in response to determining whether the closure member is being manually moved when the power actuator is off,

operating the non-contact obstacle system to detect no person while the closure member is being manually moved,

determining whether no person is detected using at least one non-contact obstacle sensor;

and

altering motion of the closure member in response to the closure member moving and no person being detected.

10. The method as set forth in claim 9, wherein the step of altering motion of the closure member in response to the closure member moving and no person being detected is

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further defined as ceasing motion of the closure member in response to the closure member moving and no person being detected.

11. A non-contact obstacle detection system for a motor vehicle comprising:

a controller adapted to connect to a power source;

at least one non-contact obstacle sensor coupled to said controller for detecting a person contacting a closure member of the motor vehicle; and

at least one of:

a power actuator coupled to the closure member and to said controller for moving the closure member and a brake mechanism coupled to said controller; wherein said controller is configured to:

detect a non-powered movement of the closure member,

operate said non-contact obstacle detection system while movement of the closure member is detected,

determine that no contact by the person with the closure member is detected using said at least one non-contact obstacle detection sensor during the non-powered movement of the closure member, and

alter movement of the closure member using said at least one of said power actuator and said brake mechanism in response to no contact by the person with the closure member being detected while non-powered movement of the closure member is detected.

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